# Atlas V Dual Spacecraft System (DSS) Preliminary Design Review (PDR)

**September 30, 2008** 



#### **Agenda**



•	1.0 Introduction/ DSS Overview	Mike Dew	8:00 - 8:25
•	2.0 System Requirements	Darrel Nesseth	8:25 – 8:40
•	3.0 DSS Requirements/Mission Success	Hank Juister	8:40 – 8:55
•	<ul> <li>4.0 Structural Design and Analysis</li> <li>4.1 Structural Design</li> <li>4.2 Loads/ Flight Dynamics</li> <li>4.3 Stress Analysis</li> </ul>	Mike Dew/Brent Viar/Ben Colvin Eric Johnson Steve Chan	8:55 – 10:00 10:00 – 11:00 11:00 – 11:20
•	<ul> <li>5.0 Systems Analysis</li> <li>5.1 Flight Design</li> <li>5.2 Shock</li> <li>5.3 Vibro-Acoustics</li> <li>5.4 Aerophysics/Venting</li> <li>5.5 Thermal Control</li> <li>5.6 Contamination</li> <li>5.7 Mass Properties</li> <li>5.8 Control Dynamics</li> <li>5.9 Safety</li> </ul>	Gary Myers Lauren Edgell Ed Heyd Cindy Camp Mike Stitt David Zimmermann Marilyn Maples Bob Utrup/Keith Pearen Darrell Ray	11:20 - 11:45 11:45 - 12:00 12:00 - 12:20 12:20 - 12:40 12:40 - 13:00 13:00 - 13:20 13:20 - 13:40 13:40 - 14:20 14:20 - 14:35



#### **Agenda**



•	<ul><li>6.0 Avionics/EMC</li><li>6.1 Avionics/Electrical/Instrumentation</li><li>6.2 EMI/EMC</li></ul>	Joven DeHerrera Greg Plamp	14:35 – 15:10 15:10 – 15:30
•	7.0 Manufacturing/Producibility	Ralph Luaces	15:30 – 16:10
•	8.0 GSE	Rez Zarei	16:10 – 16:45
•	9.0 Launch Operations	Tony Soto	16:45 – 17:10
•	10.0 Schedule	Janie Perier	17:10 – 17:20
•	11.0 Remaining Tasks/Efforts through 1st Launch	Mike Dew	17:20 – 17:35
•	12.0 Action Items	Hank Juister	17:35 – 17:50
•	13.0 Summary/Wrap-up	Cathy Andrulis	17:50 – 18:00







# Preliminary Design Review ERB 08-1364 Dual Spacecraft System

1.0 Introduction / Overview

# Mike Dew Atlas Payload Accommodations Structures Sept 30, 2008





#### This ERB presents a Preliminary Design Review of the Dual Spacecraft System

#### Reason for ERB

Present the technical design progress for the Dual Satellite System, and demonstrate sufficient technical understanding to proceed to CDR

#### Engineering Decision Required

ERB to decide whether current technical concept is mature enough to permit moving to CDR

#### Recommendation

Approve the DSS technical concept as sufficiently mature to permit continued design and analysis to move to CDR



#### PDR Entry Criteria/Checklist (from Command Media)



#### Entry Criteria/Checklist

- Requirements are complete, traceable, and verifiable?
  - > Yes see sections 2.0 and 3.0 for program and derived requirements
    - See sections 4.0 and on, for each presenters requirements and verification methodology
- Specialty Engineering and System Safety analyses of the preliminary design are complete and requirements are implemented?
  - > Yes see sections 4.0 through 9.0 specialty presentations
- Preliminary design is established?
  - > Yes see section 4.0
- Preliminary design analysis is complete?
  - > Yes see sections 4.0 and 5.0
- Preliminary design complies with requirements?
  - > Yes see sections 4.0 through 9.0
- Risks and Opportunities are updated?
  - > Yes Risk items identified in each presenters section. Opportunities (design improvements) in section 4.0
- Functional and physical interfaces are developed?
  - > Yes I/F Compatibility Analysis (ICA) to be completed prior to CDR
- Test and verification and validation plans are defined?
  - > Yes see sections 2.0 for TLYF, through 10.0. Verification methodology shown throughout PDR
- Operations planning is proceeding to schedule?
  - > Yes see section 9.0
- Program plan is validated as executable?
  - > Yes reviews (SRR/PDR/CDR) and ERB 08-1349 "DSS Engineering Concept Review " validate DSS program plan





#### · Why a DSS?

The Atlas V launch vehicle has available performance and payload accommodations to make it ideally suited for Secondary Payloads. The DSS is one of the proposed secondary payload carriers. The design of the DSS is based on currently qualified hardware- CFA, Sep Bolts, Sep Springs- and has a minimal impact on GSE and launch operations.

#### Stakeholders

- Avionics
  - > Avionics, ESD, RF Design
- Business Development, Advanced Programs
- Mission Integration
  - > Aerophysics, Contamination, Control Dynamics, Coupled Loads Dynamics, Mass Properties, Mission Design, System Safety, Thermal Control, Flight Sofware
- Harlingen Production
  - > Subcontractors
- Ground Support Equipment
- Launch Site Operations
- Structures
  - > Structures Design, Stress, Materials & Process, Space Control
- Tech Management
- Potential Customers
  - > LM Commercial Launch Services, NASA, AF, NRO
- All Stakeholders are either contributing to the development effort and are presenting at this PDR, or were invited to attend the PDR as reviewers



#### **DSS Reviews Held Prior to PDR**



- Earlier Presentations
  - - > 9/25/07, 10/16/07, 11/6/07, 4/3/08
- DSS Table Top Review (TTR), TTR-07-00896, 12/04/2007
  - \\astdfs\\data\LSD\\Upper\_Stages\\Fairings & Adapters\\DSS Dual Spacecraft
     System\\Presentations
- DSS System Requirements TTR held May 7, 2008
  - https://wgc.lockheedmartin.com/llservlet/livelink?func=ll&objld=38981970&objAction=browse&sort=name&viewType=1
- DSS Design Concept Review ERB held June 9, 2008 \malt-Im\Atlas\_Evolution\IRAD\2008\Projects\DSS-CLS\_Proposal
- DSS Systems Requirements Review held June 25, 2008
  - https://wgc.lockheedmartin.com/llservlet/livelink?func=ll&objld=40431230&objAction=browse
- Link to this PDR/ERB:
  - https://wgc.lockheedmartin.com/llservlet/livelink?func=ll&objld=43221750&objAction=browse&sort=name&viewType=1





#### DSS Top Level Requirements:

- The DSS shall fly on a Atlas V 400 vehicle
- Shall allow for two, unrelated spacecraft to be launched on the same vehicle and same launch
- Two Centaur Forward Adapter (CFA) structures, mated back-to-back, shall enclose the lower payload
  - > CFA is a skin-and-stringer structure on the Centaur that has been structurally tested, and flown many times on Atlas
- Explosive bolts will be used to separate the DSS canisters
- Have an option to insert stub adapter plugs between the canister halves to increase the envelope for the lower payload
- The existing Centaur structure shall handle the loads from the payloads and DSS





#### Design Trades:

- Canister Sep System explosive bolt brackets
- Canister sep system sep spring brackets & mating rings
- Split conic adapter for lower payload attachment
- ECS Disconnect Duct & duct routing on DSS or PLF
- Concept of Operations completed to determine a method of processing two SV's into one vehicle
  - > ConOps was presented at SRR; its an animation & will be presented here if time permits; its not part of the formal PDR
- Each of these is covered in more detail in the Structures Design presentations to follow

Spacecraft Envelope





DSS: CFA structure mated back-to-back, with or w/o plugs

DSS Canister Baseline
Design has a 2-piece conical
adapter with a Ø37" Sep
System; open to change
to accommodate specific
mission

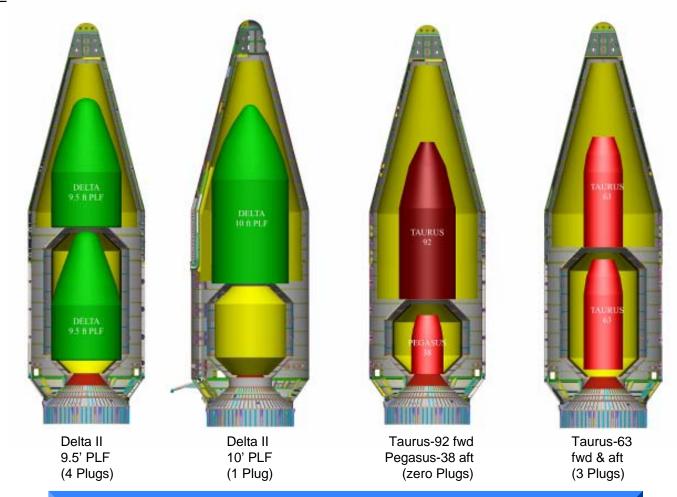
✓DSS Canister with 2 Plugs Shown

Canister Sep Plane, baseline

Spacecraft

#### **DSS Payload Envelopes**





DSS payload envelopes provide extensive coverage across small-to-medium payload space



## Accomplishments Under IRAD Funding to Date

United Launch Alliance

- Determined the need for a modal test
- Established the number of separation springs needed
- Developed a preliminary model of DSS assembly and all new parts
- Structural mass properties of all DSS configurations calculated
- Involved Harlingen in the design concept
  - > Pre-Design Kaizan scheduled for October
- Developed preliminary spacecraft envelopes for XEPF (longest PLF) with DSS
- Compared DSS envelopes with Delta II, Taurus, Pegasus, and Minotaur envelopes
- Developed preliminary mass vs. CG curves for forward SC
- Developed detailed schedule
- Developed cost estimates for each phase
- Designed an adapter for the aft SV
- Developed a list of parts removed and new parts added
- Held weekly tag-up meetings with all IPT's

- Solid modeling of various configurations
- Preliminary CLA of zero-Plug configuration
- Began 2nd CLA with a 4-Plug configuration
- Preliminary stress analysis
- Completed ROM development estimate in response to NASA inquiry (April)
- Submitted ROM estimate to LM Commercial Launch Services for DSS development post-PDR (June)
- Concept of Operations completed
- Drawing Tree created & Model Structure defined
- Met with Configuration Management to agree on model structure & EID's
- TTR's, ERB's & other reviews held
- Systems Requirements Review held 6/25/08
- Supplied autopilot modes to Flight Controls
   Group for zero plug configuration
- Evaluated several SV's at customer request for DSS space envelope compatibility

Most of these will be presented in today's PDR.







# Section 2.0 Dual Spacecraft System (DSS) System Requirements

**Darrel Nesseth** 



#### **Topics**



- Purpose
- Ground-rules and Assumptions
- Specification Approach
- Changes to Atlas V System Specification and Space Vehicle Interface (SVIR) Requirements
- System Specification Requirements Allocated to DSS
- SVIR Requirements Allocated to DSS
- Verifications
- Task Status
- Summary





 Review the approach for integration of DSS requirements into the Atlas V Specifications



#### **Ground-rules & Assumptions**



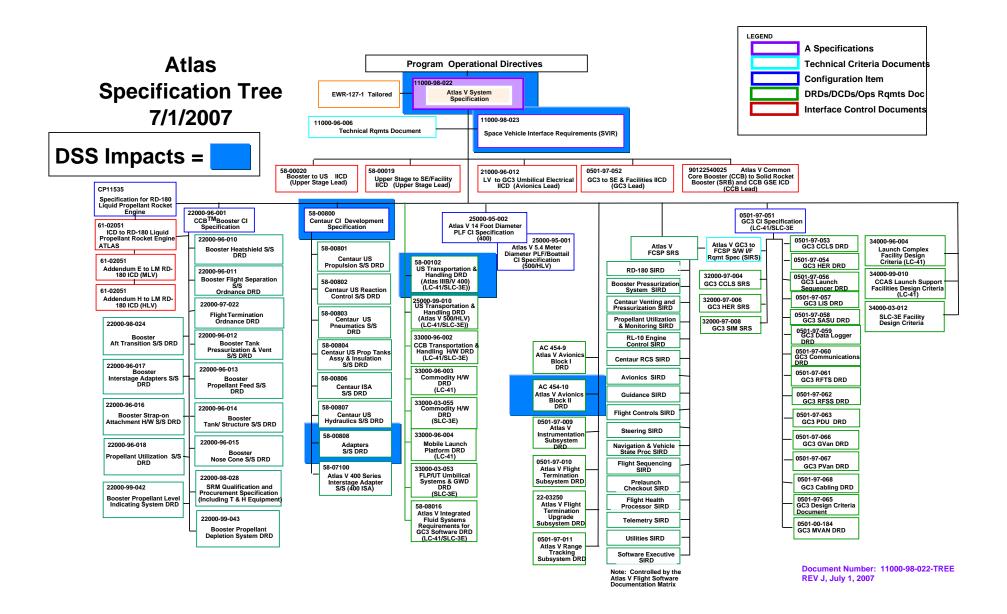
- DSS developed as an Atlas subsystem on Atlas V 400 series with LPF, EPF or XEPF
  - Delta and Atlas V 500 series compatible since integrated DSS (DSS carrier with Upper and Lower payloads) will be SIS compliant
- Initially East Coast (LC-41) only (contains more multiple payload capabilities than SLC-3E)
- Upper and Lower spacecraft will be single spacecraft (not multiple)
- Upper and Lower spacecraft missions are going to compatible orbits within configuration performance capabilities
- Three (3) independent hardware inhibits for items that could cause catastrophic events (Transmitter turn-on, Solar panel deployment, etc.)
- Baseline does not include any change in provisions for EGSE harnessing in the PVAN (No GC3 specification impacts-mission unique)



#### **Specification Approach**



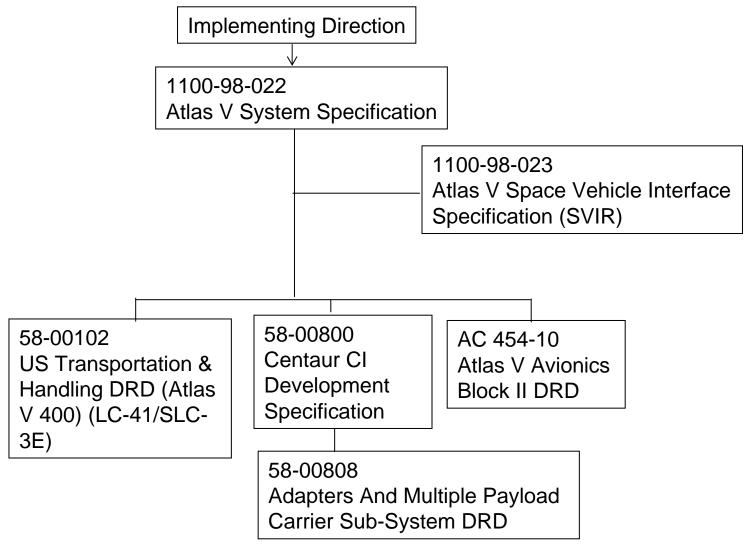
- DSS will comply with Atlas V System Specification, 11000-98-022, and Atlas V Space Vehicle Interface Requirements (SVIR), 11000-98-023
  - System Specification introduces the DSS as an Atlas V system element
  - DSS will comply with general requirements of System Specification (Allocations)
- SVIR will include DSS as a mission specific capability
  - SVIR contains flowdown of SIS (Government document) requirements
  - Integrated DSS has to satisfy payload requirements of SVIR (Allocations)
- DSS subsystem requirements will be part of the "Adapters and Multiple Payload Carriers" Sub-system DRD, 58-00808, previously named the "Adapters" DRD
- Other CIs and DRDs will contain requirements in support of DSS subsystem
  - Centaur CI Development Specification, 58-00800
  - US Transport & Handling DRD (Atlas V/400), 58-00102
  - Atlas V Avionics Block II DRD, AC-454-10
- The DSS will use standard software capabilities developed on the already-flown STP to the soon-to-be-flown DMSP





## Flow Down of Atlas V Requirements to DSS





UNITED LAUNCH ALLIANCE (ULA) PROPRIETARY INFORMATION



### Change(s) to 11000-98-022 Atlas V System Specification



- Added new words to the following paragraphs:
- 1.2 System Overview
  - -... <u>Multiple payload carriers may be used with consideration of compatibilities such as available performance, mission orbits, and other payload requirements.</u>
     ... [942]
- 3.1.1.2.5 Perform Separation
  - . . . For missions using multiple payload carriers, the upper stage flight controller will attain the separation state for each of the attached payloads. . . . [57025]
- 3.3.1.1.3 Mission Specific Requirements
  - The Atlas V systems shall comply with the mission specific requirements contained in the Atlas V Space Vehicle Interface Requirements document, 11000-98-023 section 3.2. <a href="https://documents.org/linearing-requirements">This section also includes mission unique requirements for Multiple Payload Carriers</a>. [59644]





## Change(s) to 11000-98-023 Atlas V SVIR



- Added new words to the following paragraph:
- 1.0 Scope
  - -... For LC-41, multiple payload provisions are included in the standard capabilities (Section 3.1), or as flight specific additions (Section 3.2) or as mission unique kits (Section 3.3) that can be incorporated into the Atlas V system. Multiple payloads can include dual manifested payloads, multiple spacecraft for constellation deployment or secondary payloads manifested with the primary spacecraft. Requirements for multiple payload carriers are included in Section 3.2 of this document and in DRD 58-00808, Adapters and Multiple Payload Carriers. . . . [26960]

UNITED LAUNCH ALLIANCE (ULA) PROPRIETARY INFORMATION



# Change(s) to 11000-98-023 Atlas V SVIR



- Added SVIR Section 3.2.11 as follows:
- 3.2.11 Dual Spacecraft System (DSS) Carrier
  - The Atlas V system shall provide a Dual Spacecraft System (DSS) carrier to carry two distinct payloads on compatible missions with an Atlas V 4XX with a LPF, EPF or XEPF payload fairing from LC-41. [110076]
- 3.2.11.1 Integrated DSS Mission Capabilities
  - The DSS with integrated spacecraft shall perform all mission functions within the performance specified in the Atlas V System Specification, paragraph 3.2.1.3.2, Atlas V Performance Capability, for the applicable Atlas V vehicle configuration. [110077]
- 3.2.11.2 Integrated DSS Mass Properties

payload mass properties\*

- The DSS with integrated spacecraft shall not exceed the total payload mass as specified in the SVIR, paragraph 3.1.1.2.3.1, Range of Payload Mass Properties, for an Atlas 400 series vehicle. [110078]
- 3.2.11.3 Integrated DSS Compliance with Atlas V System Specification,
  - The integrated DSS payload shall comply with all applicable requirements of the Atlas V System Specification, 11000-98-022. [110079]

[\* UPDATE SINCE SRR]





# Change(s) to 11000-98-023 Atlas V SVIR



- Added SVIR Section 3.2.11 as follows (continued):
- 3.2.11.4 Integrated DSS Compliance with SVIR
  - The integrated DSS payload shall comply with all applicable requirements of the SVIR, 11000-98-023. [110080]
- 3.2.11.5 Upper and Lower DSS Spacecraft
  - The "Adapters and Multiple Payload Carriers DRD", 58-00808, shall specify:
    - The relative weights, centers of gravity, and other properties of the Upper and Lower DSS Spacecraft
    - Other information that applies to the Upper and Lower payloads and reflects the subsystem requirements that apply to the combined and separate payloads on the DSS. [110081]



## System Requirements **Allocated to DSS**



#### 11000-98-022 Atlas V System Specification

• 3.1.1.1	Fabricate Launch Vehicle Component
• 3.1.1.2.3	Perform Jettison of Payload Fairing
• 3.1.1.2.4	Perform Upper Stage Flight
• 3.1.1.2.5	Perform Separation
• 3.1.1.2.6	Perform Post-Sep Vehicle Disposal
• 3.1.1.3	Comply with Range Safety
• 3.1.1.4	Provide Telemetry
• 3.1.1.5	Manage P/L Interfaces
• 3.1.1.6	Perform Navigation, Guidance and Control
• 3.1.1.7	Provide Vehicle Power
• 3.1.2.4	LV Element Processing
• 3.1.2.6	P/L Encapsulation
• 3.1.2.7	Encapsulated Payload Integration

Allocation Matricies are on Livelink at:

https://wgc.lockheedmartin.com/llservlet/livelink?func=ll&objid=40877007&objAction=browse&sort=name DSS PDR



## System Requirements **Allocated to DSS**



11000-98-022 Atlas V System Specification (Continued)

•	3.1.2.8	Integrated Systems Test
•	3.2.1.3.1	Spacecraft Weight Ranges
•	3.2.1.3.2	Atlas V Performance Capability
•	3.2.1.5.2	Mission Required Margin - Commercial Missions
•	3.2.2	Telemeter Key Data
•	3.2.3	Flight Control Requirements
•	3.3.1.1.1	Payload Interfaces
•	3.3.1.1.3	Mission Specific Requirements
•	3.5.2	Orbital Debris
•	3.7.1	Natural Environments
•	3.7.2	Induced Environments
•	3.7.2.2	Aerodynamic Loads
•	3.7.2.3	Limit Loads Due to Environment Transients
•	3.7.2.5	Acoustic Loads



## System Requirements **Allocated to DSS**



11000-98-022 Atlas V System Specification (Concluded)

• 3.7.2.6	Thermal Control
• 3.7.2.7	Launch Vehicle Inter Element Shock
• 3.9.1	Reliability
• 3.10.2	Stiffness and Deflections
• 3.10.4	Design Margins
• 3.10.6	Parts, Materials and Processes (PMP)
• 3.10.7	Electro Magnetic Compatibility (EMC)



# System Requirements Allocated to DSS - Example



Table 3.2.1.3.1-1 Spacecraft Weight Ranges

Launch Vehicle Configuration (See Notes)				
	400	500	HLV	
Spacecraft Weight	2,000-20,000 lbs.	3,000-42,000 lbs.	5,400-42,000 lbs.	

Notes:

- 1. Performance requirements shown in Table 3.2.1.3.2-1 through 3.2.1.3.2-15 for a given configuration may exceed system capability requirements shown above.
- 2. Atlas V 400 configurations: Maximum system capability is limited to 20,000 lbs. spacecraft weight. Mission unique analyses / accommodations may be required for spacecraft weights in excess of 20,000 lb
- 3. Atlas V 500 and HLV configurations: Government HLV GSO missions will utilize a 173 inch diameter truss adapter interface. Maximum system capability for spacecraft interface to the equipment module is limited to 20,000 lbs. spacecraft weight. Spacecraft weights ranging from 20,000 lbs. to 42,000 lbs. may require mission unique analyses / accommodations.
- 4. Spacecraft weights in excess of 42,000 lbs. may require mission unique analyses / accommodations (LV interfaces, LV design modifications, GSE modifications, etc.)





11000-98-023 Atlas V Space Vehicle Interface Requirements (SVIR)
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• 3.1.1.1.1	Atlas V 400 Series Launch Vehicle SV Envelopes
• 3.1.1.1.2	Payload Stay-Out Zones
• 3.1.1.2.1	Coordinate System Definition
• 3.1.1.2.2	Standard Interface Plane (SIP) Attachments
• 3.1.1.2.2.1.1	Atlas V 400 Interface
• 3.1.1.2.2.2	Flatness
• 3.1.1.2.3.1	Range of Payload Mass Properties
• 3.1.1.2.3.2	Atlas V 400 Series Vehicles SV Structural Stiffness
• 3.1.1.2.3.2.1	Atlas V 400 SV Interface Load
• 3.1.1.2.3.5	SV/Atlas V Interface Load Transfer
• 3.1.1.2.3.6	Atlas V SV Lifting Points
• 3.1.1.2.4	Space Vehicle Access Provisions
• 3.1.1.2.4.1	Payload Fairing Routine Access Doors
• 3.1.1.2.4.2	Access to SVs-Timelines
• 3.1.1.2.4.3	Payload Fairing Emergency Access Provisions





11000-98-023 Atlas V Space Vehicle Interface Requirements (SVIR) (continued)

• 3.1.2.1	Standard Electrical Interface Panel (SEIP)
• 3.1.2.1.1	Standard Electrical Interface Panel (SEIP) Harness Connections
• 3.1.2.1.2	SEIP Mating Connector Halves
• 3.1.2.2	T-0 and Payload Circuit Dead Facing
• 3.1.2.3.1	SV Ground Power Umbilical Wiring for Multiple Payloads (LC-41 Only)
• 3.1.2.3.2	SV Ground Power Umbilical Wiring Resistance
• 3.1.2.3.3	SV Ground Power Umbilical Wire Rating
• 3.1.2.4.1	SV Signal Umbilical Wiring for Multiple Payloads (LC-41 Only)
• 3.1.2.4.2	SV Signal Umbilical Wiring Resistance
• 3.1.2.4.3	SV Signal Umbilical Wire Rating
• 3.1.2.4.4	SV Umbilical Serial Data Lines
• 3.1.2.4.4.1	SV Umbilical Serial Data Lines for Multiple Payloads (LC-41 Only)
• 3.1.2.5	Flight Command and Telemetry Interface
• 3.1.2.5.1	Atlas V System to Satellite Vehicle Commands
• 3.1.2.5.1.1	Command Capability
• 3.1.2.5.1.2	Discrete Commands
• 3.1.2.5.1.3	Switch Closure Functions
• 3.1.2.5.2.1	Separation Ordnance Power
• 3.1.2.5.2.2	Separation Ordnance Circuit

• 3.1.2.5.2.3

Electro-Explosive Device (EED) Firing Circuits





#### 11000-98-023 Atlas V Space Vehicle Interface Requirements (SVIR) (continued)

0-90-023 Alias v	Space vehicle interface Requirements (SVIR) (continu
• 3.1.2.5.2.4	Separation Ordnance Firing Signals
• 3.1.2.5.2.5	Firing Signal Single Pulse Duration
• 3.1.2.5.2.6	Minimum Firing Current
• 3.1.2.5.2.7	Maximum Firing Current
• 3.1.2.5.2.8	Firing Signal Separation Time
• 3.1.2.5.2.9	Additional SV Separation Provisions for Multiple Payloads
• 3.1.2.5.3.1	Command Monitors
• 3.1.2.5.3.2	Separation Indication
• 3.1.2.5.3.3.1	Analog Monitors
• 3.1.2.5.3.3.2	Command Verification Monitors
• 3.1.2.5.3.3.3	Accelerometer Monitors
• 3.1.2.5.3.4	Payload Serial Data Interface
• 3.1.2.5.3.4.1	Serial Data Characteristics
• 3.1.2.5.3.4.2	Serial Data Sample Characteristics
• 3.1.2.5.3.4.3	Serial Data Rates
• 3.1.2.5.3.5	Satellite Telemetry Transmission
• 3.1.2.5.3.5.1	RF Communication in VIF (LC-41) and MST (SLC-3E)
• 3.1.2.5.3.5.2	SV RF Communication Uplink and Downlink
• 3.1.2.5.3.5.3	LV/SV Orientation
• 3.1.2.5.3.6	State Vector Data
• 3.1.2.5.3.6.1	State Vector Data for Multiple Payloads

DSS PDR 30 Sep 2008 State vector Data for infultiple Payioads





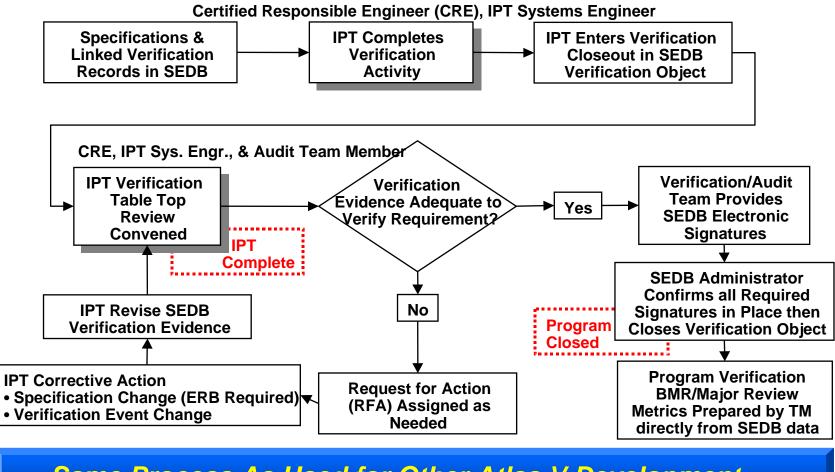
11000-98-023 Atlas V Space Vehicle Interface Requirements (SVIR) (concluded)

• 3.1.2.6	Electromagnetic Compatibility
• 3.1.3.1	Thermal
• 3.1.3.2	Contamination
• 3.1.3.3	Acoustics
• 3.1.3.4	Vibration
• 3.1.3.5	Shock
• 3.1.3.6	Acceleration Load Factors
• 3.1.3.7	PLF Pressure Decay Rate
• 3.1.4.1	Park and Transfer Orbits
• 3.1.4.2	Final Orbit
• 3.1.4.3	Separation Requirements
• 3.1.5.1	SV Encapsulation
• 3.1.5.2	Encapsulated SV Transport to Vertical Integration
	Facility (VIF) and Mobile Service Tower (MST)
• 3.1.5.3	Encapsulated Payload Hoist and Mate
• 3.1.5.5	Integrated SV/PLF Transport to Launch Pad (LC-41 Only)
• 3.1.5.6	On the Launch Pad (LC-41) and After MST Rollback (SLC-3E)



#### **Requirements Verification Process**





Same Process As Used for Other Atlas V Development



#### **System Level Verifications (In SEDB)**



Number	Name	Method	Resp Org	Scheduled Finish
GND-SYS-A-001-4XX-DSS	Ground Handling & Interfaces 4XX-DSS	A	A5 Structures	2/30/2011
LV-SYS-A-001-4XX-DSS	Performance & Mass Properties 4XX-DSS	A	A5 Mission Integration	2/28/2011
LV-SYS-A-034-4XX-DSS	Telemetry and Flight Instrumentation 4XX-DSS	A	A5 Avionics	3/30/2011
LV-SYS-A-036-4XX-DSS	Reliability 4XX-DSS	А	A5 Reliability	1/30/2011
LV-SYS-A-037-4XX-DSS	Fabrication 4XX-DSS	I	A5 Structures PMP	3/30/2011
LV-SYS-A-038-4XX-DSS	Range Safety 4XX-DSS	A	Safety	2/28/2011
LV-SYS-A-039-4XX-DSS	Electrical Interfaces 4XX-DSS	I	A5 Avionics	1/30/2011
LV-SYS-A-040-4XX-DSS	Environmental Assessment 4XX-DSS	A	A5 Mission Integration	2/28/2011
LV-SYS-A-041-4XX-DSS	Structural & Flight Capabilities 4XX-DSS	A	A5 Structures Stress	4/30/2011
LV-SYS-A-050-4XX-DSS	Electromagnetic Interfaces 4XX-DSS	А	A5 Avionics	3/30/2011



#### Task Status



- System Requirements Review (SRR) approved DSS requirements/verification approach
- System level (System Specification and SVIR) requirements approved and entered into Systems Engineering Data Base (SEDB)
- Applicable system requirements have been allocated to impacted DSS specifications
- System verification are proposed with links to impacted requirements in SEDB with preliminary schedules
- Parent/child traceability of requirements to subsystems and design is the topic of this PDR and will continue to CDR



#### **Summary**



- Architecture for DSS requirements was approved at SRR
- Atlas V System (including SVIR) requirements are identified, allocated to DSS design and integration and entered into SEDB
  - New system level requirements are approved
  - Existing system requirements that apply to DSS were identified and allocated to design
- System verifications are identified with preliminary schedule dates
- PDR will detail impact of requirement on design and implementation of DSS

#### **Ready To Proceed to CDR**







## Section 3.0 DSS Derived Requirements

Hank Juister



#### **Topics**



- Action Items from SRR
- Systems Engineering Process
- Mission-Success Considerations
- DSS Impact to other documents
- DSS Derived Requirements
  - Completeness
  - Traceability to parent requirements
  - Verification Methodology & ECDs
- CDR Tasks
- Summary



#### **Action Items from SRR**



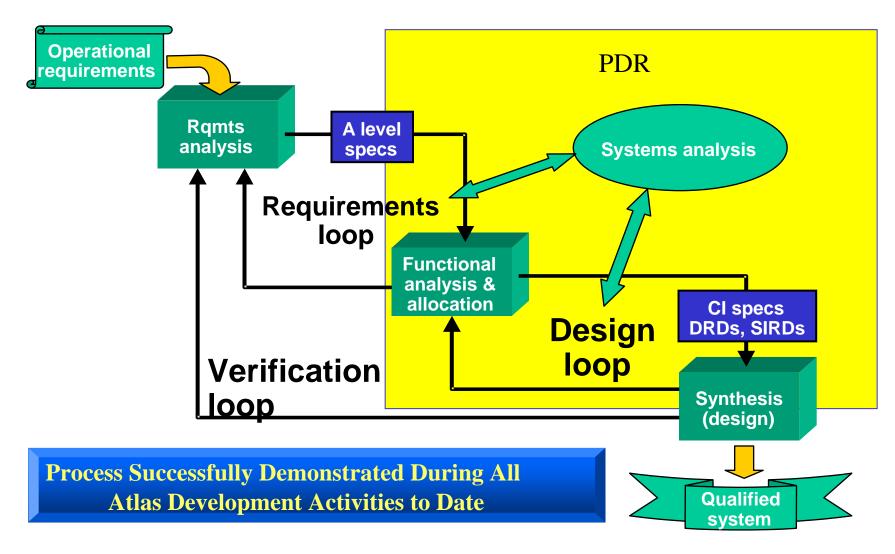
#### INFORMAL ACTIONS / DIRECTIONS:

- 1. Para 3.2.4.3.9.3.1: DSS mass should be minimized consistent with existing hardware. (Done updated my SRR charts to show this as a goal, not a requirement)
- 2. Bracket para. 3.2.4.3.9.5.4.1 (Done instead of brackets, I updated my charts to show Contingency Clearance as a goal, not a requirement)
- Show SC Envelopes are preliminary (Done updated my SRR charts to show this and put changes into SEDB)
- 4. If upper SC fails to separate from DSS what is the impact?
   (Done covered in this PDR)
- 5. Push the SC weight and CG forward to determine what the structural capability is. (Done – covered in this PDR)
- Address safety implications from limited lower SC access by PDR. (Done – covered in this PDR)
- 7. Baseline short coast, two burn mission and that the 2 payloads do not conflict in environmental requirements. (Done – covered in this PDR)
- FORMAL ACTIONS:
  - None



#### **Systems Engineering Process**







#### **Mission-Success Considerations**



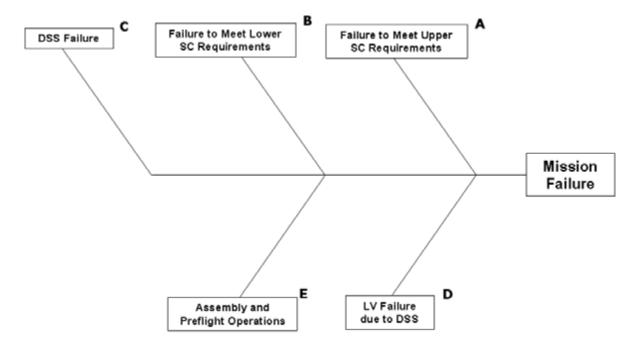
- Items to be covered in detail @ CDR:
  - Potential failure analysis
    - All potential failures must be evaluated with a potential to adversely affect mission outcome (e.g., FMEA, Fishbones), with each cause & effect identified & mitigations discussed
    - Process in work (see next 6 charts)
  - Compatibility Analysis
    - Mission-critical interfaces will be verified for compatibility as drawings are released
  - Test-Like-You-Fly (TLYF) considerations
  - Reliability



#### **Fishbones**



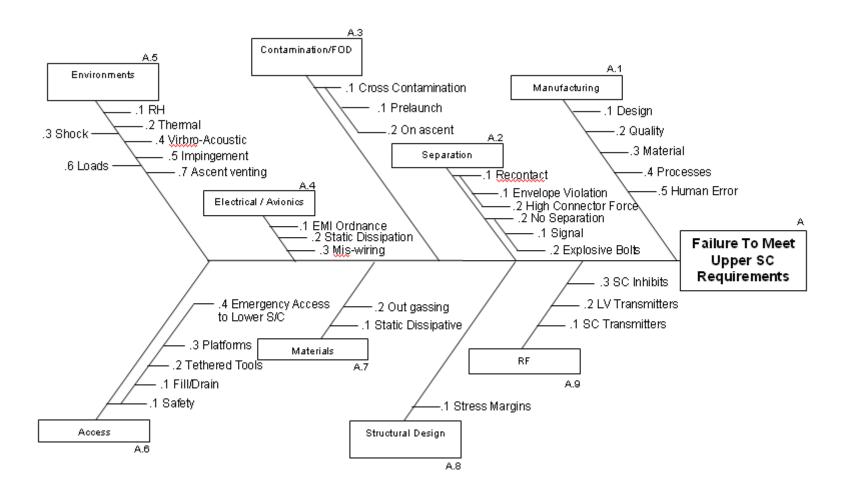
- 5 Main Failure Modes Identified (shown on next 5 charts)
- 122 Total Sub-Modes
- 17 Dispositioned/Closed
  - 14 % Total
  - Dispositions require review and approval





#### Fishbones ("A" bone)

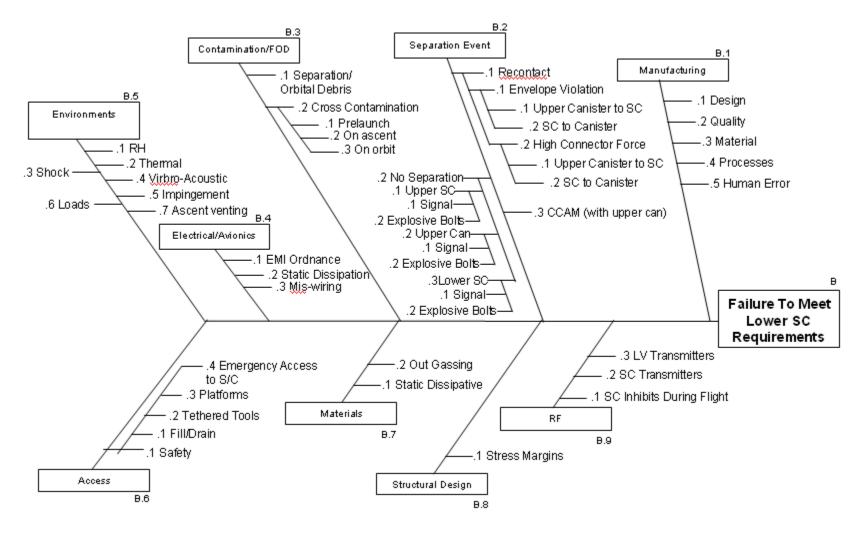






#### Fishbones ("B" bone)

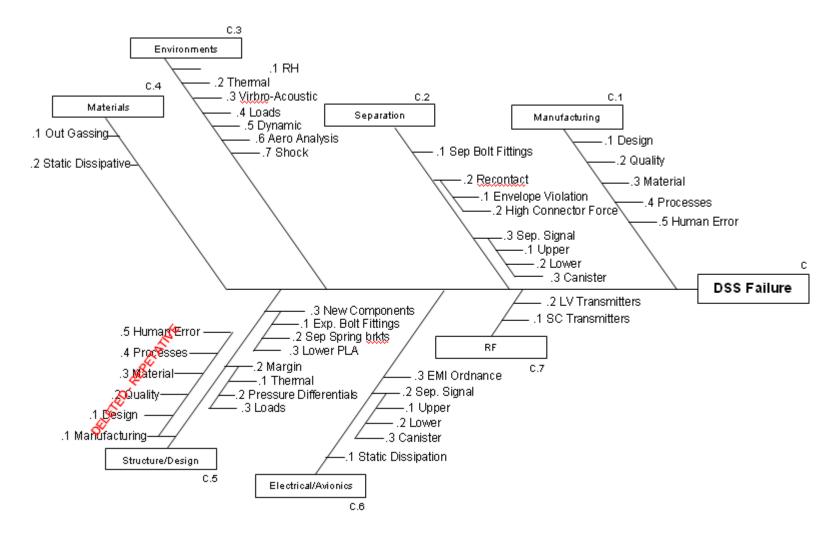






#### Fishbones ("C" bone)

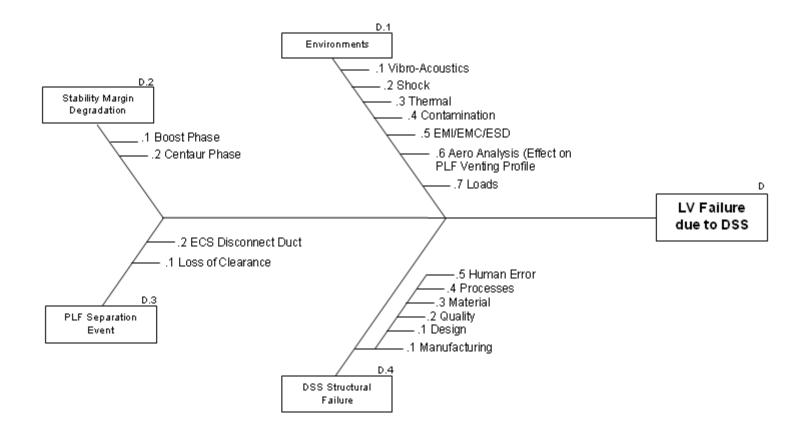






## Fishbones ("D" bone)

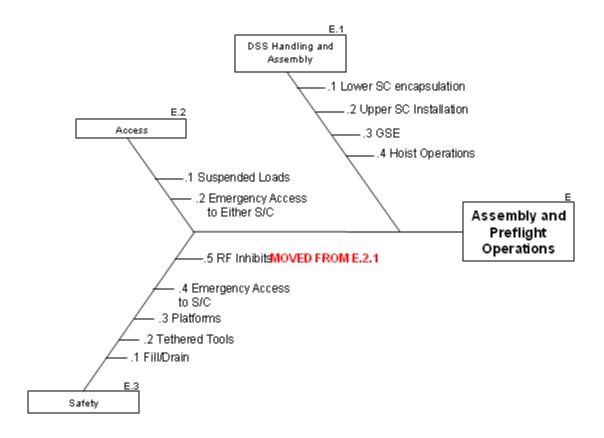






### Fishbones ("E" bone)







## **DSS Impact to other documents**



- Section 2.0 covered System Spec and SVIR impacts
- Other documents impacted:
  - T&H (58-00102 DRD)
  - Centaur (58-00800 CI)
- No impacts:
  - AC 454-10 (Avionics)
  - AV FCSP (SRS) (Software) Standard Atlas V software being used for DSS



## **T&H (58-00102 DRD)**



 Changes and updates to 58-00102 will be covered in Section 8.0 "GSE"



## Centaur (58-00800 CI)



- 3.1.1.7 Adapters Subsystem (info, only)
  - Add DSS description: "The Dual Spacecraft System (DSS) is composed of two (2) Centaur Forward Adapters (CFAs) and, depending on the size of the spacecraft, from 0 to 4 Plug adapters derived from the Stub Adapter portion of the CFA."
- 3.2.4.3.3 Spacecraft Mating (requirement)
  - Add DSS mating requirement: "When the DSS is used to launch two (2) spacecraft, the mechanical/structural interfaces for the spacecraft shall be the DSS."



## **Derived Requirements**



- All derived requirements presented @ SRR and redlines incorporated into SRR package (on LL) and put into SEDB
  - Derived requirements are shown on following 6 pages
- Derived and System requirements will be addressed today in the following presentations – any changes/updates from this PDR will be incorporated into the derived requirements in SEDB
- Added @ PDR Flip-thru:
  - 3.2.4.3.9.3.2 (DSS CG Offset) "The DSS Upper Canister CG offset shall be no more than [1.0 inch]."
     (WAS: "The DSS CG offset, from centerline of the LV, shall be no more than 1.0 inch.")



## **DSS Derived Requirements**



- 1.0 SCOPE
- 1.1 DSS Description
- This document describes the derived design requirements for the Atlas V 400 series Dual Spacecraft Subsystem (DSS).

•

- 2.0 DOCUMENTS
- 3.0 REQUIREMENTS
- 3.2.4.3.9 Dual Spacecraft System (DSS)
- The Dual Spacecraft System (DSS) is composed of two (2) Centaur Forward Adapter structures, mated back to back that enclose the aft/lower payload, plus a modified C13 Adapter and several additional components shown in figure 3.2.4.3.9-1. Flight qualified 4m PLF explosive bolts will be used to separate the DSS lower and upper canisters. The DSS Plug adapters are derived from the Stub Adapter portion of the Centaur Forward Adapter.





- 3.2.4.3.9.1 DSS Load Path
- 3.2.4.3.9.1.1 Structural Support and Load Path
- The DSS Shall provide structural support and load path for upper and lower payloads.
- 3.2.4.3.9.1.2 Centaur Support of Payloads and DSS
- Existing Centaur structure shall support the loads from the upper and lower payloads and DSS.
- 3.2.4.3.9.2 Mass Properties, S/C
- Mass properties of the payloads shall be constrained to not exceed the structural capability of the Centaur and DSS, as the DSS structure is derived from the existing/flight qualified Centaur Forward Adapter (CFA).
- 3.2.4.3.9.2.1 Upper S/C
- Upper S/C shall not exceed [10,000 lbs] with mass vs. CG of TBD
- 3.2.4.3.9.2.2 Lower S/C
- Lower S/C shall not exceed [5,000 lbs] with mass vs. CG of TBD





- 3.2.4.3.9.3 Mass Properties, DSS
- 3.2.4.3.9.3.1 DSS Weight
- DSS weight should be minimized consistent with design philosophy of using existing hardware.
- 3.2.4.3.9.3.2 DSS CG Offset
- The DSS CG offset, from centerline of the LV, shall be no more than 1.0 inch.
- 3.2.4.3.9.4 DSS Finish
- The DSS shall have an exterior finish of white paint and interior finish of Chemfilm.
- 3.2.4.3.9.5 DSS Separation Requirements
- 3.2.4.3.9.5.1
- The DSS shall use 6 existing designed 4m PLF separation bolts for separating upper canister from lower canister.
- 3.2.4.3.9.5.2 Standard Separation Plane
- The standard separation plane shall be at the top of the lower canister, regardless of the number plugs.
- 3.2.4.3.9.5.3 DSS Separation Shock
- DSS separation shock shall not exceed S/C or Centaur avionics allowables or as specified in TRD 11000-96-006.





- 3.2.4.3.9.5.4 Upper Canister Separation
- Once the separation bolts function, [4] springs (PN 55-78632-4) will "thrust" the upper canister away from lower canister so that no contact occurs with the lower S/C or lower canister.
- 3.2.4.3.9.5.4.1 Contingency Clearance
- As a contingency for failure of the upper S/C to separate from the DSS, the DSS should, as a goal, be designed so that the upper canister will provide adequate clearance, from the lower S/C, with the upper S/C still attached.]
- 3.2.4.3.9.6 Interfaces
- 3.2.4.3.9.6.1 DSS to Centaur I/F
- DSS to Centaur I/F shall be C13 adapter (existing I/F).
- 3.2.4.3.9.6.2 DSS to S/C I/Fs
- DSS to S/C I/Fs shall be compatible with the 47" and/or 37" SAAB Clamp Band separation systems for both S/C.
- 3.2.4.3.9.6.3 DSS to GSE/Avionics
- DSS to GSE/Avionics (see 3.2.4.3.9.7 below)
- 3.2.4.3.9.6.4 DSS to ECS
- DSS to ECS (see 3.2.4.3.9.9 below)
- 3.2.4.3.9.6.5 DSS to S/C Electrical/Instrumentation
- DSS to S/C Electrical/Instrumentation (see 3.2.4.3.9.10 below)





- 3.2.4.3.9.7 Attach Points
- 3.2.4.3.9.7.1 Attach Points for Avionics Cables/Disconnects
- DSS shall have provisions for attaching avionics cables/disconnects.
- 3.2.4.3.9.7.2 T&H GSE Attach Points
- DSS shall have provisions for attaching T&H GSE.
- 3.2.4.3.9.7.3 Torus Interface
- Torus interface shall be at the same location (height, clocking, radial distance) on the C-13 adapter.
- 3.2.4.3.9.8 Access
- Access through the DSS shall be by existing openings in DSS and plug adapters. (Existing openings provides hand/arm access only; no full body access is provided.).
- 3.2.4.3.9.9 ECS
- 3.2.4.3.9.9.1 ECS Interface with DSS for Lower S/C
- The DSS shall have 'sleeve' joint for A/C into lower S/C to provide [100] lbs air/min. to lower S/C. ECS will interface with a diffuser on the DSS to provide air to the lower SC. SC purges are considered mission unique & not included.
- 3.2.4.3.9.9.2 Cross Contamination-Upper/Lower S/Cs
- The DSS will minimize cross contamination between the upper and lower S/Cs.





- 3.2.4.3.9.10 Electrical/Instrumentation for S/C
- The DSS shall provide attach brackets for MPK wires to each S/C. (DSS will not provide release switches to sense S/C release. S/C must have its own release switch that tells it that it has been released.)
- 3.2.4.3.9.11 Payload Envelopes (XEPF)
- 3.2.4.3.9.11.1 No DSS Plug Adapters
- [With no DSS plug adapters, the DSS envelopes shall be as shown in Figure 3.2.4.3.9.11-1]
- 3.2.4.3.9.11.2 One (1) DSS Plug Adapters (XEPF)
- [With one (1) DSS plug adapter, the DSS envelopes shall be as shown in Figure 3.2.4.3.9.11-2]
- 3.2.4.3.9.11.3 Two (2) DSS Plug Adapters (XEPF)
- [With two (2) DSS plug adapters, the DSS envelopes shall be as shown in Figure 3.2.4.3.9.11-3]
- 3.2.4.3.9.11.4 Three (3) DSS Plug Adapters (XEPF)
- [With three (3) DSS plug adapters, the DSS envelopes shall be as shown in Figure 3.2.4.3.9.11-4]
- 3.2.4.3.9.11.5 Four (4) DSS Plug Adapters (XEPF)
- [With four (4) DSS plug adapters, the DSS envelopes shall be as shown in Figure 3.2.4.3.9.11-5]



## **Requirements Traceability**



 Currently, the DRD 58-00808 requirements are traced to parent requirements. The DSS requirements will be 'linked' to most of the same parent requirements when the DSS is added to the 58-00808 document in SEDB.



#### **Requirements Traceability (continued)**



58-00808 Para No.	Title	Comments	Atlas V System Spec.	Atlas V SVIR	Centaur Spec	Other Spec.s/ DRDs/Comments
3.0	Requirements	Title	N/A	N/A	N/A	N/A
3.2.4.3.9	Dual Spacecraft System (DSS)	Information	N/A	N/A	N/A	N/A
3.2.4.3.9.1	DSS Load Path	Title	N/A	N/A	N/A	N/A
3.2.4.3.9.1.1	Structural Support and Load Path		3.3.1.1.3	3.2.11.1/.2, 3.1.1.2.3.5		
3.2.4.3.9.1.2	Centaur Support of Payloads and DSS		3.1.1.2.4, 3.1.1.5			
3.2.4.3.9.2	Mass Properties, S/C		3.2.1.3.1	3.1.1.2.3.1		
3.2.4.3.9.2.1	Upper S/C		3.2.1.3.1	3.1.1.2.3.1		
3.2.4.3.9.2.2	Lower S/C		3.2.1.3.1	3.1.1.2.3.1		
3.2.4.3.9.3	Mass Properties, DSS	Title	N/A	N/A	N/A	N/A
3.2.4.3.9.3.1	DSS Weight		3.1.1.2.3.1	3.2.11.1/.2/.3		
3.2.4.3.9.3.2	DSS CG Offset		3.1.1.6, 3.2.3			
3.2.4.3.9.4	DSS Finish		3.10.6			
3.2.4.3.9.5	DSS Separation Requirements	Title	N/A	N/A	N/A	N/A
3.2.4.3.9.5.1	Separation Bolts		3.1.1.2.5./.6, 3.5.2	3.3		
3.2.4.3.9.5.2	Standard Separation Plane		3.3.1.1.3			
3.2.4.3.9.5.3	DSS Separation Shock					
3.2.4.3.9.5.4	Upper Canister Separation	Option Only	N/A	N/A	N/A	N/A
3.2.4.3.9.5.4 .1	Contingency Clearance	Info Only	N/A	N/A	N/A	N/A
3.2.4.3.9.6	Interfaces	Title	N/A	N/A	N/A	N/A



#### **Requirements Traceability (continued)**



			Parent/Sibling Documents				
58-00808 Para No.	Title	Comments	Atlas V System Spec.	Atlas V SVIR	Centaur Spec	Other Spec.s/ DRDs/Comments	
3.2.4.3.9.6.1	DSS to Centaur I/F		•	3.3.1.1.1	3.1.1.2.3.5		
3.2.4.3.9.6.2	DSS to S/C I/Fs			3.3.1.1.1			
3.2.4.3.9.6.3	DSS to GSE/Avionics	Info only	N/A	N/A	N/A	N/A	
3.2.4.3.9.6.4	DSS to ECS	Info only	N/A	N/A	N/A	N/A	
3.2.4.3.9.6.5	DSS to S/C Electrical/Instrumentation	Info only	N/A	N/A	N/A	N/A	
3.2.4.3.9.9.7	Attach Points	Title	N/A	N/A	N/A	N/A	
3.2.4.3.9.7.1	Attach Points for Avionics Cables/Disconnects						
3.2.4.3.9.7.2	T&H GSE Attach Points		3.1.1.7				
3.2.4.3.9.7.3	Torus Interface		3.1.2.7, 3.1.1.1				
3.2.4.3.9.9	ECS	Title	N/A	N/A	N/A	N/A	
3.2.4.3.9.9.1	ECS Interface with DSS for Lower S/C						
3.2.4.3.9.9.2	Cross Contamination- Upper/Lower S/Cs						
3.2.4.3.9.10	Electrical/Instrumentation for S/C		3.1.2.8	3.1.2.1/1.1			
3.2.4.3.9.11	Payload Envelopes (XEPF)	Title	N/A	N/A	N/A	N/A	
3.2.4.3.9.11.	No DSS Plug Adapters			3.1.1.1.2			
3.2.4.3.9.11. 2	One (1) DSS Plug Adapters (XEPF)			3.1.1.1.2			



#### Requirements Traceability (concluded)



			Parent/Sibling Documents			
58-00808	Title	Comments	Atlas V System	Atlas V SVIR	Centaur Spec	Other Spec.s/
Para No.			Spec.			DRDs/Comments
3.2.4.3.9.11.	Two (2) DSS Plug Adapters			3.1.1.1.2		
3	(XEPF)					
3.2.4.3.9.11.	Three (3) DSS Plug			3.1.1.1.2		
4	Adapters (XEPF)					
3.2.4.3.9.11.	Four (4) DSS Plug Adapters			3.1.1.1.2		
5	(XEPF)					
3.						
	END	OF	DSS	TRACE		



## Requirements Verification



Number	Name/Description	Method	Resp Org	Scheduled Finish
DSS 3.2.4.3.9.1.1	DSS structural support	А	A5 Structures	9/30/09
DSS 3.2.4.3.9.1.2	Centaur Structural support	A	A5 Structures	9/30/09
DSS 3.2.4.3.9.2	Mass Properties, S/C	A	A5 Structures/MI	9/30/09
DSS 3.2.4.3.9.2.1	Upper S/C	T (weigh S/C)	A5 Structures/MI	9/30/09
DSS 3.2.4.3.9.2.2	Lower S/C	T (weigh S/C)	A5 Structures/MI	9/30/09
DSS 3.2.4.3.9.3.2	CG offset	A, T (weigh DSS)	A5 Structures/MI	A-9/30/09 T-7/30/10 (Pathfinder)
DSS 3.2.4.3.9.4	Finish	I	A5 Structures	9/30/09
DSS 3.2.4.3.9.5.1	DSS separation bolts	I	A5 Structures	9/30/09



#### Requirements Verification (continued)



Number	Name/Description	Method	Resp Org	Scheduled Finish
DSS 3.2.4.3.9.5.2	Standard separation plane	I	A5 Structures	9/30/09
DSS 3.2.4.3.9.5.3	Shock	A	A5 Structures/MI	9/30/09
DSS 3.2.4.3.9.5.4	Separation springs	A	A5 Structures/MI	9/30/09
DSS 3.2.4.3.9.6.1	DSS-Centaur I/F	I	A5 Structures	9/30/09
DSS 3.2.4.3.9.6.2	DSS-S/C I/Fs	I	A5 Structures	9/30/09
DSS 3.2.4.3.9.7.1	Attach points, avionics	I, D	A5 Structures	9/30/09 D-7/30/10 (Pathfinder)
DSS 3.2.4.3.9.7.2	Attach points, T&H	I, D	A5 Structures	9/30/09 D-7/30/10 (Pathfinder)
DSS 3.2.4.3.9.7.3	Attach points, Torus	I, Pathfinder	A5 Structures/OPS	9/30/09 I-7/30/10 (Pathfinder)



#### Requirements Verification (concluded)



Number	Name/Description	Method	Resp Org	Scheduled Finish
DSS 3.2.4.3.9.8	Access	I, Pathfinder	A5 Structures	9/30/09 I-7/30/10 (Pathfinder)
DSS 3.2.4.3.9.9.1	ECS to lower S/C	I, A, D	A5 Structures/MI	9/30/09 D-7/30/10 (Pathfinder)
DSS 3.2.4.3.9.10	Electrical/Instrumentation for S/C	I, A, D	A5 Structures	9/30/09 D-7/30/10 (Pathfinder)
DSS 3.2.4.3.9.11.1	P/L Envelopes (XEPF, no plug adapters)	I, A	A5 Structures	9/30/09
DSS 3.2.4.3.9.11.2	P/L Envelopes (XEPF, 1 plug adapter)	I, A	A5 Structures	9/30/09
DSS 3.2.4.3.9.11.3	P/L Envelopes (XEPF, 2 plug adapters)	I, A	A5 Structures	9/30/09
DSS 3.2.4.3.9.11.4	P/L Envelopes (XEPF, 3 plug adapters)	I, A	A5 Structures	9/30/09
DSS 3.2.4.3.9.11.5	P/L Envelopes (XEPF, 4 plug adapters)	I, A	A5 Structures	9/30/09



## Tasks Prior to end of 2008



- Work specification documents
  - Complete parent/child traceability of requirements in SEDB
  - Work to resolve all TBDs and bracketed items



#### **CDR Tasks**



- Work specification documents
  - Update 58-00808 DRD
    - Complete parent/child traceability of requirements in SEDB
    - Resolve all TBDs and bracketed items
    - Hold Atlas V ERB to incorporate DSS requirements into released Atlas V document system
    - Release updates in ADM
  - Work with Centaur and T&H POCs to update their DRDs
- Ensure Mission Success Considerations are addressed



#### Summary



DSS derived requirements and process meet the Atlas V programs requirements

#### **Ready To Proceed to CDR**







# Preliminary Design Review ERB 08-1364 Dual Spacecraft System

#### 4.0 DSS Structural Design & Analysis

- 4.1 Structures
- 4.2 Dynamics
- 4.3 Stress

**Sept 30, 2008** 





# Preliminary Design Review ERB 08-1364 Dual Spacecraft System

# 4.1.1 DSS Structures Design

Mike Dew, Brent Viar, Ben Colvin

Atlas Payload Accommodations Structures Sept 30, 2008



# Nest Structures Design



- Structures Groundrules & Assumptions as evolved during PDR design phase
  - Adapters and sep systems for both SC are considered Mission Unique at this time; awaiting identification of SV's
  - Harlingen will manufacture DSS canisters and plugs using same or similar tooling they use to build CFA's
  - A Modal Test is required, as determined in meetings with Dynamics, Stress and Design
  - Verification of the Dynamic Model will also verify the overall stiffness
  - Canister separation shock testing will not be done; (sep bolts are identical to those used currently on 4m PLF, are fewer in number and located further from CEM & SV I/F than the PLF bolts; as a result, shock attenuation is greater)
  - The small number of new components such as explosive bolt fittings, spring brackets, connector brackets, etc. will be designed to a F.S. of 2.0 based on Ultimate with no testing; or, alternatively, they will be designed to a FS of 1.25 with tests
  - A Pathfinder payload processing sequence will be performed



## **DSS Structures Design**

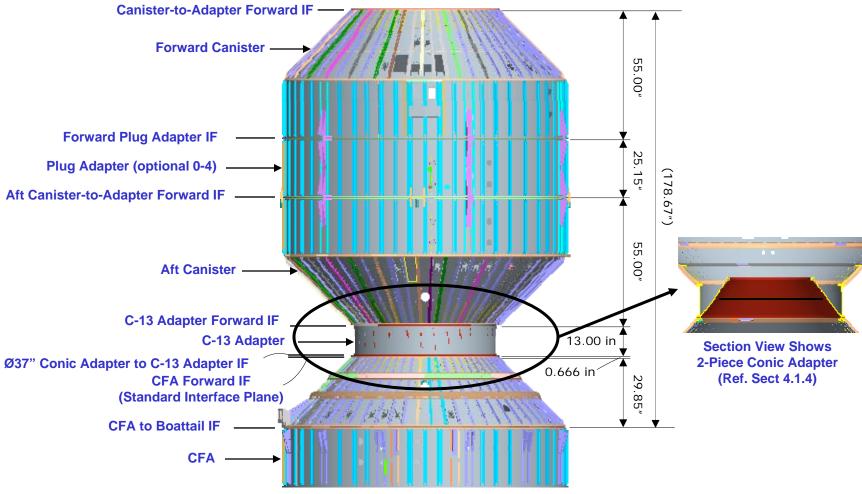


- Structures Ground Rules & Assumptions as evolved during PDR design phase
  - Modal test article will be used as first flight article (Protoflight unit)
  - No structural, separation or shock tests will be done on the overall DSS structure; some component structural tests may be required
    - ➤ CFA is a tested, flight-proven structure; goal is to use structural design as is, i.e., no cutting or removal of stringers; which drives next ground rule
  - Access to aft spacecraft within canister provides hand/arm access only; no full body access is provided
  - Both spacecraft will be identified at 24 months prior to ILC with computer models provided to ULA for loads analysis
  - Any changes to the existing A/C duct for the forward SV are considered mission unique
  - An ECS will interface with a diffuser on the DSS to provide air to the aft SV
  - Minimize cross-contamination between forward and aft SV's
  - SV purges are considered mission unique
  - A requirement for re-tensioning or re-preloading of the sep systems on forward or aft payloads after PL processing is considered mission unique since the sep systems are not identified at this time



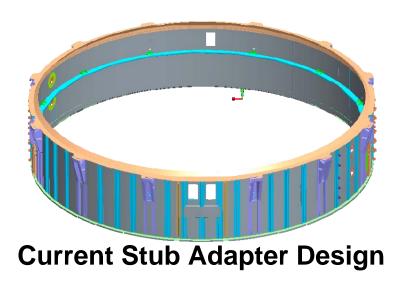


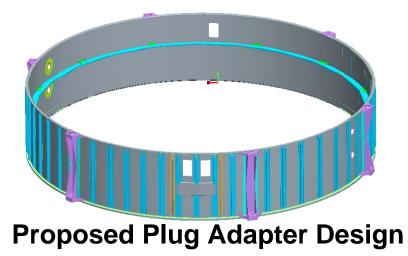
#### Payload Adapters will be Mission Unique; A 2-Piece Conic Adapter was assumed for preliminary design, analysis & PL processing



# **DSS Plug Adapter**







# Differences between a Stub Adapter & a DSS Plug

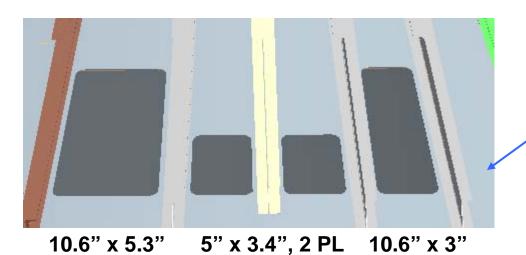
- Replace Boattail I/F Ring with aft I/F ring
- Replace 6 of the separation bolt brackets with new design. Brackets oriented with cone-coupling facing aft and cup-coupling facing forward
- Replace the 6 remaining separation bolt brackets with typical stringer
- Remove Ground Plane mounting hardware and brackets
- Replace PLF Hinge brackets and adjacent stringers with typical stringer

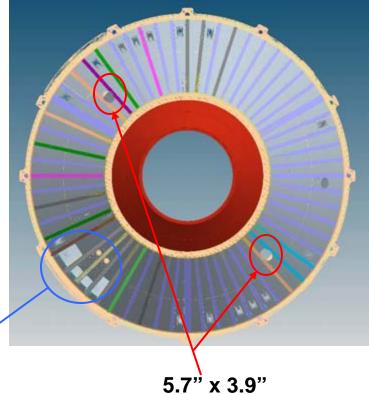


# DSS Existing Access Ports



- Existing equipment module cutouts that could be used as access ports or ECS ingress
- Same size openings could be placed at other locations



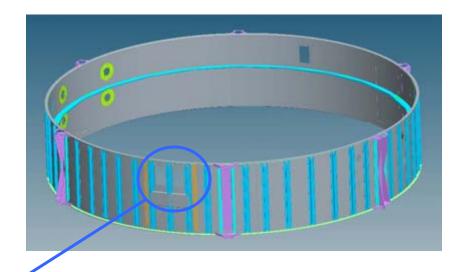


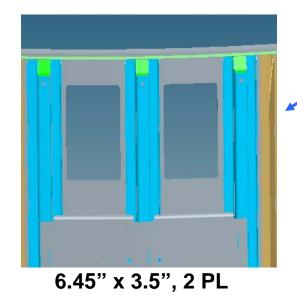


# DSS Existing Access Ports



- Existing cutouts that could be used as access ports or ECS ingress
- Same size openings could be placed at other locations





Existing cutouts are large enough for hand or arm access to SV; could be used for special tool access to SV



# DSS Drawing Tree



DSS - Dual Spacecraft System Drawing Tree AV-4 LV EID 22-0010 EID 22-00010-x Product Structure organized with End Items in consultation with EID 58-30000 **Configuration Management** DSS Array 58-70000-xxx DSS At: SubAssy Insti DSS Fwd SubAssy Insti 58-70001 58-70002 Fwd DSS GENERAL ARRANGEMENT 58-70012-x At DSS GENERAL ARRANGEMENT 58-70011-x DSS Fwd SubAnny Struc 58-70001-x 58-70002-x LOWER PAYLOAD ADPTR Inst 58-70010 C-13 P/L ADAPTER 58-0438 DSS FWD CANISTER EID 58-XXXX AVIONICS PACKAGE DSS AFT CANISTER 58-XXXX DSS PLUG EID 58-XXXX AVIONICS PACKAGE MPK EID 58-XXXX DSS FWD CANISTER Intel 58-70004 LOWER PAYLOAD ADPTR Stu 58-70010-x C-13 P/L ADAPTER DSS AFT CANSTER Insti 58-70003 DSS PLUG Insti 58-70005 58-XXXXX-x 58-00438-x AFT ADPTR STUC PLUG ADPTR Struc 58-70005-x FWD ADPTR Sourt 58-70004-x DSS MICD SS-XXXXXX-x 58-70003-x SEP BOLT BRKT Inc. SEP BOLT BRKT Ins SEP BOLT BRICT Inst 58-300000C-x 58-3000000-a 58-0000006-v 58-300000 58-XXXXXX-W (Structures Product) (DSS P.N.) COVER Inst 55-74805-x COVER Inst 55-74905-x 58-70000-301 COVER INI 55-74805-x 58-XXXXXX 58-XXXXXX NOTE: THE SEPARATION PLANE IS ON THE IDENT PLATE Inst IDENT PLATE Insti IDENT PLATE Insti FORWARD INTERFACE OF THE AFT CANISTER 58-77671-1 58-T76T1-x 58-77671-1 FOR THE DSS BASELINE CONFIGURATION

Revised May 20, 2008



### Part Mods for a CFA-to-DSS Conversion



#### Part Modifications to Both Forward and Aft Canister Adapters

\*All modifications and quantities are typical of each canister adapter unless noted otherwise in the Description section

Item	Part Number	Quantity	Description	Change
1	NAS1779RC4	182	Nut Plates along Stub Adapter IF Ring	Removed
2	55-77669-2	1	Main Umbilical Bracket Front	Removed
3	55-74834-5	1	Main Umbilical Bracket Top	Removed
4	55-74834-4	7	L-Brackets Connecting Items 2 & 3	Removed
5	55-74831-1	1	Tapered Umbilical Bracket Gusset to Stringer	Removed
6	55-74831-2	1	Tapered Umbilical Bracket Gusset to Stringer	Removed
7	55-74831-3	3	Tapered Umbilical Bracket Gusset to Stringer	Removed
8	55-74831-4	1	Tapered Umbilical Bracket Gusset to Stringer	Removed
9	55-74831-5	6	Gusset to Stringer L-Bracket	Removed
10	NAS1149C0432R	10	Umbilical Bracket Fastening Hardware	Removed
11	NAS6304U7	7	Umbilical Bracket Fastening Hardware	Removed
12	NAS6304U8	3	Umbilical Bracket Fastening Hardware	Removed
13	96-37609-002	15	Umbilical Bracket Fastening Hardware	Removed
14	NAS1153E2	9	Umbilical Bracket Fastening Hardware	Removed
15	NAS1149D0363J	10	Umbilical Bracket Fastening Hardware	Removed
16	NAS1003-3A	10	Umbilical Bracket Fastening Hardware	Removed
17	MS21043-3	10	Umbilical Bracket Fastening Hardware	Removed
18	NAS1149D0332J	11	Umbilical Bracket Fastening Hardware	Removed
19	NAS1101E3-7	11	Umbilical Bracket Fastening Hardware	Removed
20	MS21060L3	5	Umbilical Bracket Fastening Hardware	Removed
21	58-77646-1	2	Electrical Disconnect Bracket	Removed



# Part Modifications (cont.)



Part Modifications For Forward and Aft Canister Adapters (Continued)

Item	Part Number	Quantity	Description	Change
22	55-57591-1	2	LH2 Duct Brackets	Removed
23	55-57591-2	2	LH2 Duct Brackets	Removed
24	55-57591-3	1	Harnessing Bracket	Removed
25	58-65514-1	1	Harnessing Bracket	Removed
26	55-57591-4	2	Bracket Supports for Item 27	Removed
27	55-74833-2	1	Electrical Disconnects Bracket Mounting Bracket	Removed
28	55-57591-6	1	Bracket Support for Item 27	Removed
29	NAS1671-08L2	2	Fastening Hardware for Item 27	Removed
30	NAS1149DN832J	2	Fastening Hardware for Item 27	Removed
31	55-74813-10	1	Avionics Mounting Rail	Removed
32	55-74813-6	1	Avionics Mounting Rail	Removed
33	55-74838-1	2	LH2 Duct Bracket	Removed
34	55-74800-97	4	LH2 Duct Bracket Shims	Removed
35	55-78121-3	4	PLF Hinge Bracket	Removed
36	58-77685-2	20	Ground Plate Mounting Posts	Removed
37	58-77685-4	5	Ground Plate Mounting Posts	Removed
38	58-77685-1	35	Ground Plate Mounting Posts	Removed
39	NAS1329A3K80	60	Fastening Hardware for Ground Plate Posts	Removed
40	JNP-0002	4	Fastening Hardware for Item 41	Removed
41	58-77685-3	2	Spacer Bracket for the Antenna Ground Plane	Removed
42	55-79880-7	12	Separation Bolt Bracket	Removed



# Part Modifications (cont.)



Part Modifications For Forward and Aft Canister Adapters (Continued)

Item	Part Number	Quantity	Description	Change
43	55-78183-11	2	Stringer Support For Item 35	Removed
44	55-78183-12	2	Stringer Support For Item 35	Removed
45	55-78183-13	2	Stringer Support For Item 35	Removed
46	55-78183-14	2	Stringer Support For Item 35	Removed
47	96-37609-001	32	Fastening Hardware for Item 42	Removed
48	55-78190-STUBFEM	6	Separation Bolt Bracket on Aft Canister Adapter*	Added
49	55-78122-8	1	Aft Interface Ring of Stub Adapter	Removed
50	55-78122-8_DSS	1	Modified Aft Interface Ring of Stub Adapter	Added
51	55-78167_DSS	12	Support Stringers Adjacent to Separation Bolt Brackets	Added
52	SEP_SPRING_BKT_1	4	Separation Spring Bracket	Added
53	55-78632-4	4	Separation Spring Assembly on Aft Canister Adapter*	Added
54	55-78132-25	10	Stub Adapter Stringer Assembly	Added
55	55-78190-STUB_FOR	6	Separation Bolt Bracket on Forward Canister Adapter*	Added



# Part Modifications (cont.)



Part Modifications to DSS Plug Adapter

\*Part Modifications are typical to all plug adapter regardless of position in DSS unless noted otherwise in the Description section.

Item	Part Number	Quantity	Description	Change
PA1	58-77691-1	1	Boattail Interface Ring	Removed
PA2	55-78122-8	1	Aft Interface Ring	Removed
PA3	55-78121-3	4	PLF Hinge Bracket	Removed
PA4	55-78183-11	2	PLF Hinge Bracket Support Stringer	Removed
PA5	55-78183-12	2	PLF Hinge Bracket Support Stringer	Removed
PA6	55-78183-13	2	PLF Hinge Bracket Support Stringer	Removed
PA7	55-78183-14	2	PLF Hinge Bracket Support Stringer	Removed
PA8	55-79880-7	12	Separation Bolt Bracket Assembly	Removed
PA9	55-77685-2	20	Ground Plate Attachment Post	Removed
PA10	55-77685-4	5	Ground Plate Attachment Post	Removed
PA11	55-77685-1	35	Ground Plate Attachment Post	Removed
PA12	NAS1329A3K80	60	Fastening Hardware for Items PA9, PA10, & PA11	Removed
PA13	58-77685-3	2	Spacer Bracket for the Antenna Ground Plane	Removed
PA14	96-37609-001	32	Fastening Hardware for Item PA8	Removed
PA15	JNP-0002	4	Fastening Hardware for Item PA13	Removed
PA16	55-78122-8_DSS	2	DSS Interface Ring	Added
PA17	55-78190-STUB_FOR	6	DSS Separation Bolt Bracket	Added
PA18	55-78190-STUBFEM	6	DSS Separation Bolt Bracket	Added
PA19	55-78167_DSS	12	Stringer Adjacent to Items PA17 & PA18	Added
PA20	55-78132-25	10	Stringer Assembly	Added





- Design description & discussion of some of the new components for a DSS follow
  - -Brent Viar, Ben Colvin
- Dynamics Analysis follows Design
  - -Eric Johnson
- Stress Analysis follows Dynamics
  - -Steve Chan





# Section 4.1.2 - Design Separation Bolts and Fittings

Brent Viar
Atlas Payload Accommodations Structures
Sept 30, 2008





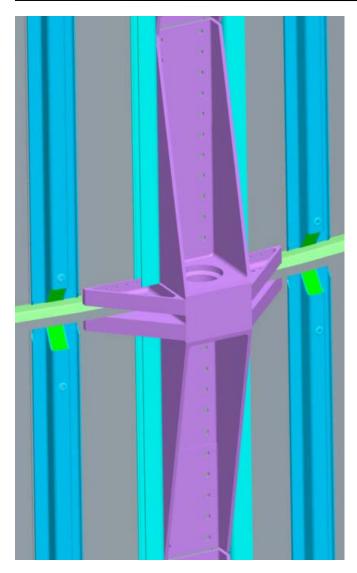
## Separation Bolts and Fittings - Topics United Launch Alliance

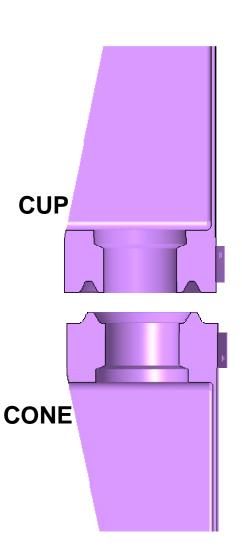
- Separation Bolt Fitting Design Overview
- DSS Requirements
- Compliance of preliminary design with requirements
- Verification of requirements





### **Separation Bolts and Fittings – Design**





#### **Key Features of Fittings:**

- Cup-Cone Interface between forward and aft brackets
- Gussets to distribute shear forces into stub adapter interface ring
- Modeled after CFA/PLF Sep Bolt Fitting Design
- Fittings will be attached to skin





# Separation Bolts and Fittings - Requirements United Launch Alliance

#### Bolts:

- 3.2.4.3.9 Flight qualified 4m PLF explosive bolts will be used to separate the DSS fwd and aft canisters.
- 3.2.4.3.9.5.1 The DSS shall use 6 existing designed 4m PLF separation bolts for separating fwd canister from aft canister

### Fittings:

- 3.3.2.3.1 The separation bolt fittings shall be designed to a safety factor of 2.0 if untested, or 1.25 if tested.
- 3.3.2.3.1.1 The margin of safety for the fittings shall be positive for all design conditions.





#### **Separation Bolts and Fittings – Compliance**

 3.2.4.3.9 - Flight qualified 4m PLF explosive bolts will be used to separate the DSS fwd and aft canisters.

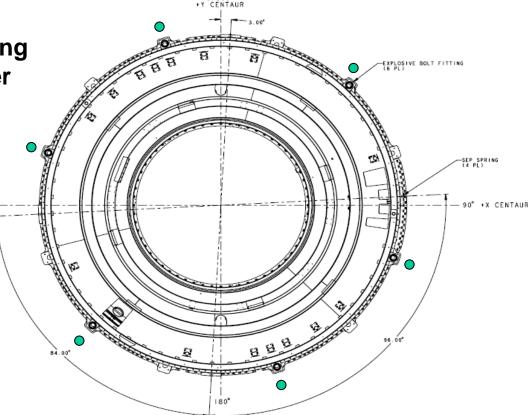
 3.2.4.3.9.5.1 – The DSS shall use 6 existing designed 4m PLF

separation bolts for separating

fwd canister from aft canister

 6 existing designed 4m PLF separation bolt locations

Verification - Inspection







#### **Separation Bolts and Fittings – Compliance**

- 3.3.2.3.1 The separation bolt fittings shall be designed to a safety factor of 2.0 if untested, or 1.25 if tested.
- 3.3.2.3.1.1 The margin of safety for the fittings shall be positive for all design conditions.
  - Fitting design is similar to CFA/PLF separation bolt fitting

Verification - Analysis





# Section 4.1.3 - Design Separation Spring Brackets

Brent Viar
Atlas Payload Accommodations Structures
Sept 30, 2008





# **Separation Springs – Topics**

- Separation Springs Design Overview
- DSS Requirements
- Compliance of preliminary design with requirements
- Verification of requirements



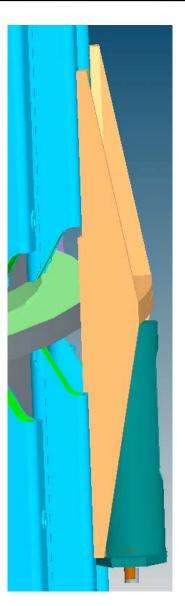


## **Separation Springs – Design**

#### **Bracket option**



Brackets would be riveted to the stringers

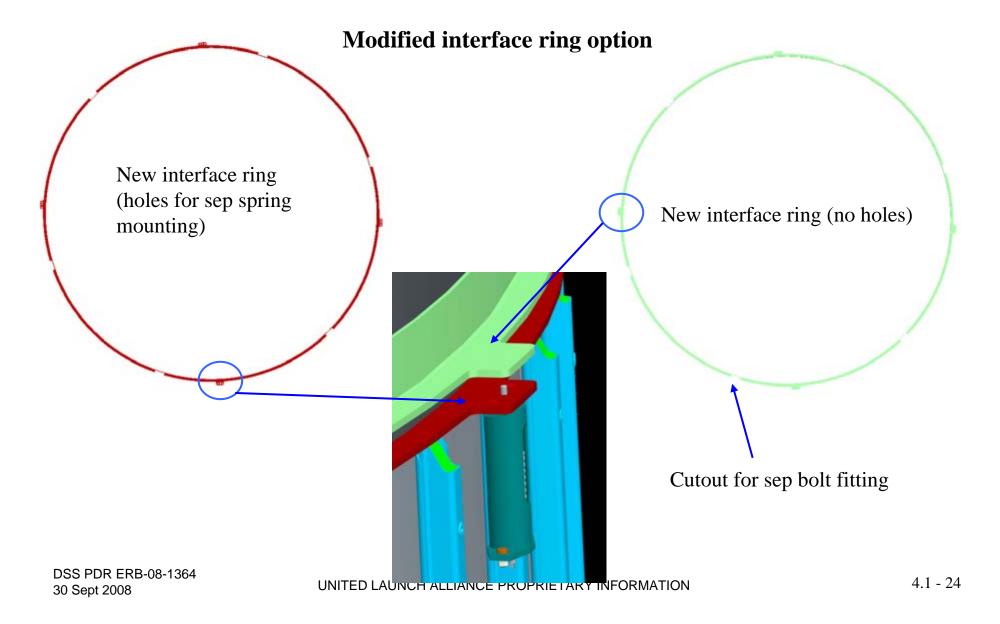


DSS PDR ERB-08-1364 30 Sept 2008





# **Separation Springs – Design**







#### <u>Separation Springs – Requirements</u>

- 3.2.4.3.9.5.4 Once the separation bolts function [4] springs will thrust the fwd canister away from the aft canister so that no contact occurs with the aft S/C or aft canister
- 3.3.2.3.1 The interface ring shall be designed to a safety factor of 2.0 if untested, or 1.25 if tested.
- 3.3.2.3.1.1 The margin of safety for the interface ring shall be positive for all design conditions.



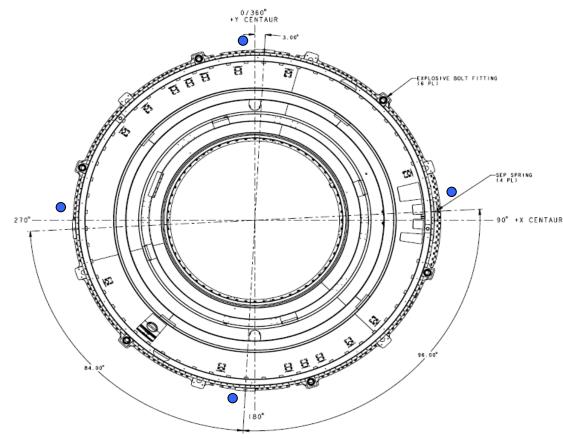


### **Separation Springs- Compliance**

• 3.2.4.3.9.5.4 – Once the separation bolts function [4] springs will 'thrust' the fwd canister away from the aft canister so that no contact occurs with the aft S/C or aft canister

• 4 existing separation spring locations

Verification - Inspection







### **Separation Springs- Compliance**

- 3.3.2.3.1 The interface ring shall be designed to a safety factor of 2.0 if untested, or 1.25 if tested.
- 3.3.2.3.1.1 The margin of safety for the interface ring shall be positive for all design conditions.
  - The interface ring design will meet the standard design criteria

Verification - Analysis





# Section 4.1.4 - Design Aft Payload Two-Piece Conic Adapter

# Brent Viar Atlas Payload Accommodations Structures Sept 30, 2008





#### <u>Aft Payload Two-Piece Conic Adapter – Topics</u>

- DSS Requirements
- Compliance of preliminary design with requirements
- Verification of requirements





#### Lower Payload Two-Piece Conic Adapter - Requirement Snited Launch Alliance

- New components shall be designed with a FS of
  2.0 based on Ultimate with no structural testing
  - -3.2.4.3.9.2.2 Aft S/C Aft S/C shall not exceed [5,000 lbs] with mass vs. CG of TBD



30 Sept 2008

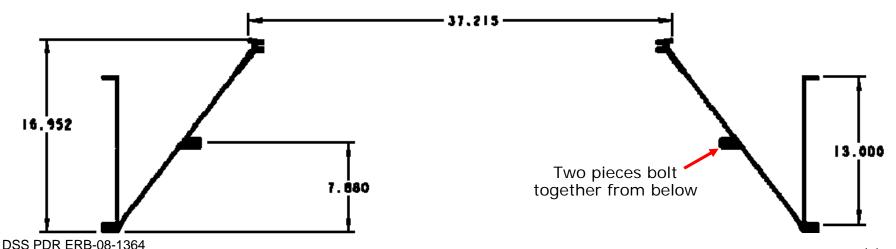


#### Lower Payload Two-Piece Conic Adapter - Compliance United Launch Alliance

- New components shall be designed with a FS of 2.0 with no structural testing
  - -3.2.4.3.9.2.2 Aft S/C Aft S/C shall not exceed [5,000 lbs] with mass vs. CG of TBD
  - Aft Payload Two-Piece Conic Adapter will be designed and analyzed for a FS of 2.0

Verification - Analysis

#### **Conceptual Design Shown**







# Preliminary Design Review ERB 08-1364 Dual Spacecraft System

# 4.1.4 Lower Environmental Control System

Ben Colvin
Atlas Payload Accommodations Structures
Sept 30, 2008





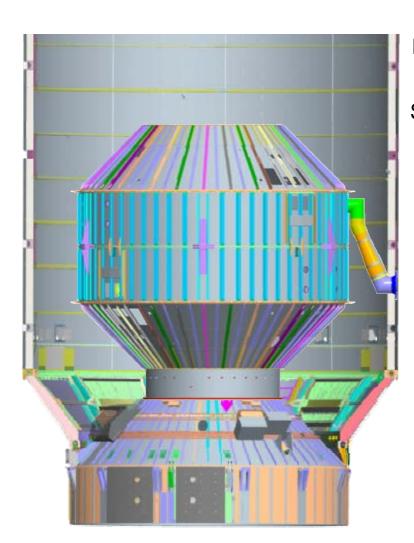
# Lower ECS - Topics

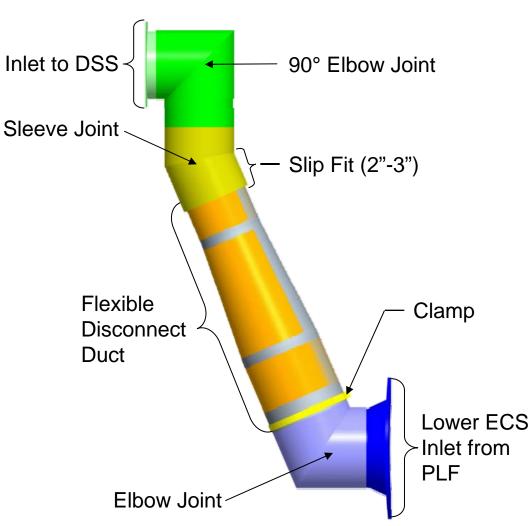
- Lower ECS Design Overview
- DSS Requirements
- Compliance of preliminary design with requirements
- Verification of requirements





# Lower ECS - Design Concept A

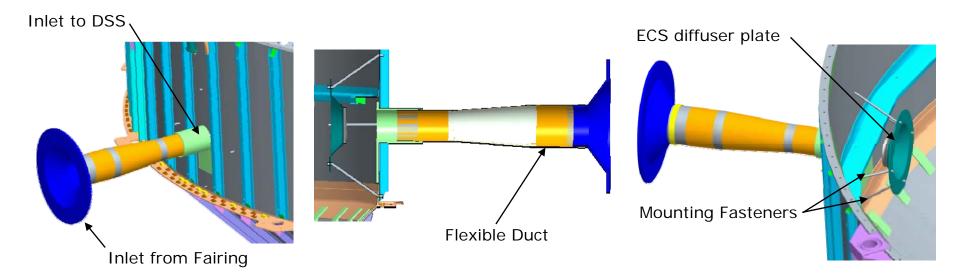








# **Lower ECS – Design Concept B**



#### • Concept C, not shown:

- Vertical ducting attached to PLF with horizontal flexible duct into DSS
- Flexible duct similar to designs used on other missions
  - Made from Vapor-Deposited Gold material for electro-static discharge considerations





# <u> Lower ECS – Requirements</u>

- Shall be compatible with LPF, EPF and XEPF fairings
- Shall be compatible with all DSS configurations
- An ECS shall interface with a diffuser/deflector plate on the DSS to provide air to the aft SV
- 3.2.4.3.9.9.1 The DSS shall have 'sleeve' joint for A/C into lower S/C to provide [100] lbs air/min to aft S/C. ECS will interface with a diffuser on the DSS to provide air to the aft S/C.

### **Other Related Requirements**

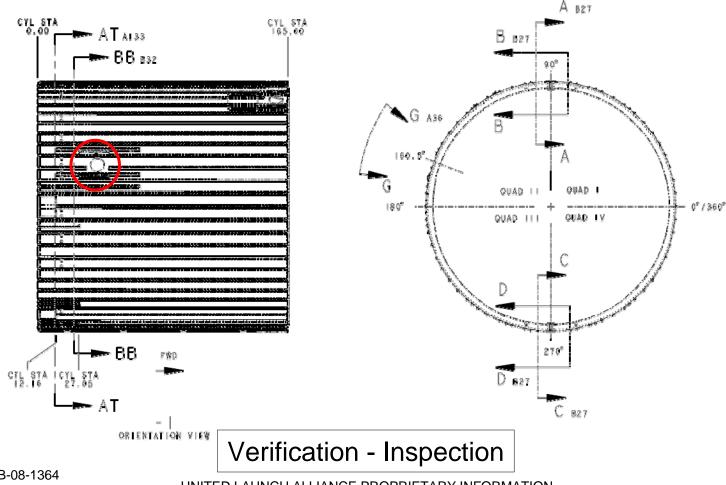
- 3.2.4.3.9.9.2 The DSS will minimize cross contamination between the fwd and aft S/Cs.
- The PLF air/GN2 distribution system shall provide a maximum air flow velocity less than 32 fps for Atlas 400.





# **Lower ECS – Compliance**

- Shall be compatible with LPF, EPF and XEPF fairings
  - Lower ECS inlet from the fairing is identical for each fairing





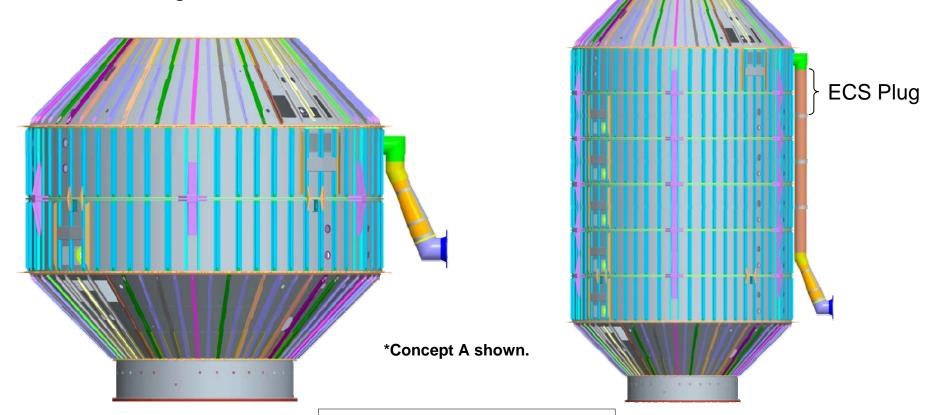


## Lower ECS - Compliance

Shall be compatible with all DSS configurations

- Plugs available to extend ducting to required length for each DSS

configuration



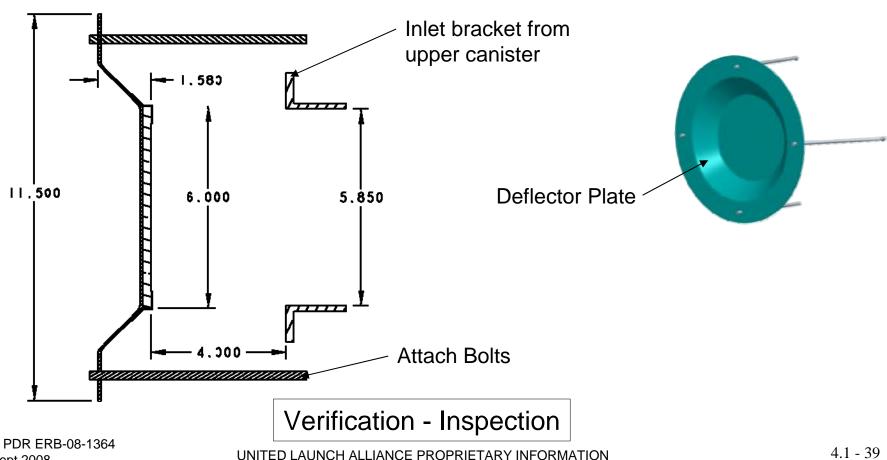
Verification - Inspection





## Lower ECS – Compliance

- An ECS shall interface with a diffuser/deflector plate on the DSS to provide air to the aft SV
  - Deflector plate based on Delta vehicle design flown currently



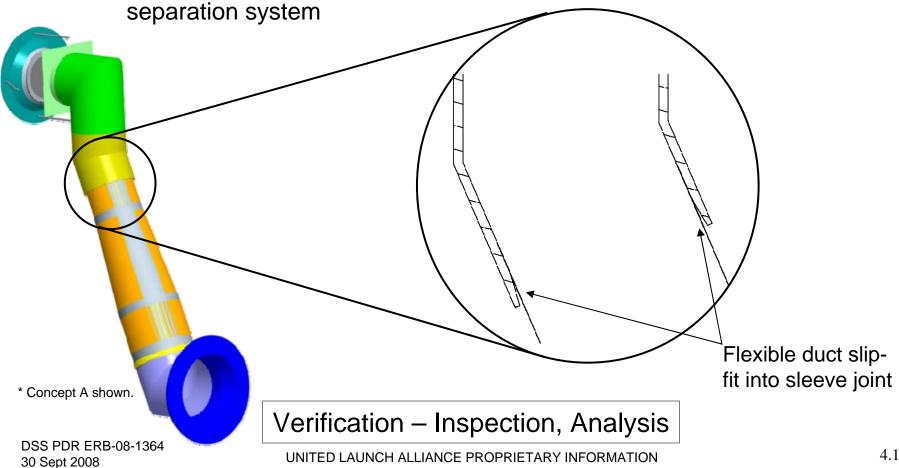




## Lower ECS – Compliance

• 3.2.4.3.9.9.1 – The DSS shall have 'sleeve' joint for A/C into aft S/C to provide [100] lbs air/min to lower S/C.

- DSS Lower ECS uses flexible duct with slip-fit to act as a passive



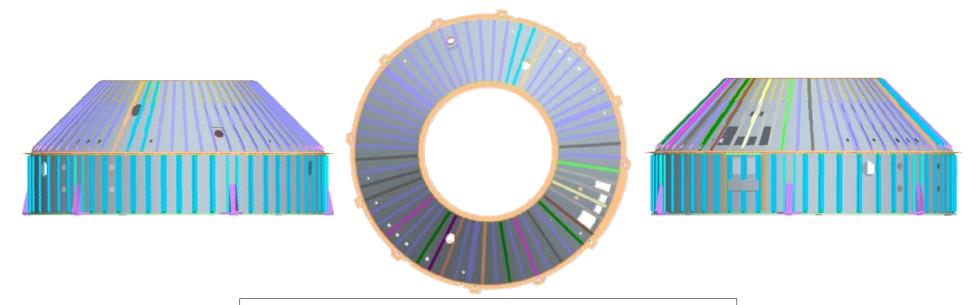




## Lower ECS – Compliance

### **Other Related Requirements**

- 3.2.4.3.9.9.2 The DSS will minimize cross contamination between the fwd and aft S/Cs.
  - ECS inlet to DSS is in the forward canister
  - Work with Aerophysics to determine which holes in the forward canister need to be plugged







## Lower ECS - Compliance

### Other Related Requirements Cont...

- The PLF air/GN2 distribution system shall provide a maximum air flow velocity less than 32 fps for Atlas 400.
  - Structures and Aerophysics working together to size ECS inlet in order to meet air flow velocity requirements

Verification - Analysis





## **Lower ECS – Verification**

Number	Name/Description	Method	ECD
	Shall be compatible with LPF, EPF and XEPF fairings	I	
	Shall be compatible with all DSS configurations	I	
	An ECS shall interface with a diffuser/deflector plate on the DSS to provide air to the aft SV	I	
3.2.4.3.9.9.1	The DSS shall have 'sleeve' joint for A/C into aft S/C to provide [100] lbs air/min to aft S/C.	I, A	
3.2.4.3.9.9.2	3.2.4.3.9.9.2 – The DSS will minimize cross contamination between the fwd and aft S/Cs.	A (Mission Specific)	
	The PLF air/GN2 distribution system shall provide a maximum air flow velocity less than 32 fps for Atlas 400.	А	





- Areas of Risk & Mitigation
  - Payload access door in canister required?
    - Ground Rule that arm access only will be provided
    - > Design allows for clocking with respect to SV
    - > Design allows for additional openings to be cut in skin
  - ECS ducting or manifolding within canister required?
    - > If ducting is required, it will be handled as mission unique

DSS structural design is considered low-risk; moving to next design phase with confidence



## Structures Section 4.1 Summary



- Maturity of DSS design meets the success criteria for a PDR
  - Design of new components to create a DSS is well underway, and no insurmountable obstacles have been identified
- DSS derived requirements are reasonable, compatible with existing system requirements – as discussed in earlier SRR
- Analysis to date verifies DSS is compatible with Atlas V 400 for loads, vibro-acoustics, shock environments (upcoming sections)
- Additional static structural testing not required
  - Some component level tests may be required for new components
  - For example, Sep Bolt Fittings, Sep Spring Brackets, ECS Disconnect
- Modal survey test, with high level excitation, satisfies requirements for dynamic model & overall stiffness verification
- Risks and mitigations identified

### **Ready To Proceed to CDR**



## **Appendix**

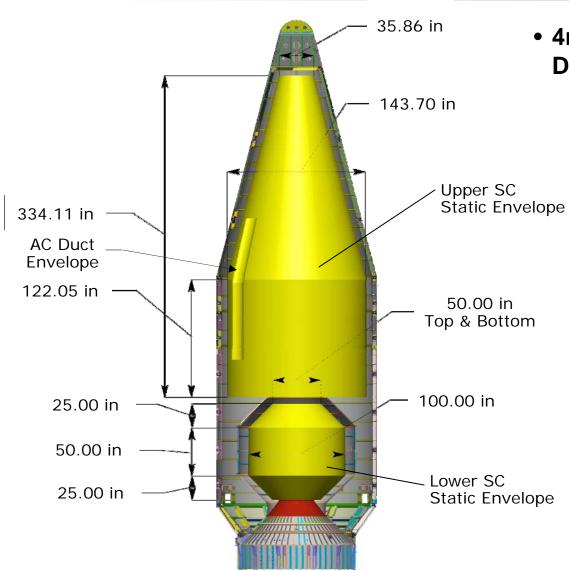


### **DSS Payload Envelopes – Preliminary**

Zero Plugs to 4-Plugs

## **Payload Envelopes - Preliminary**

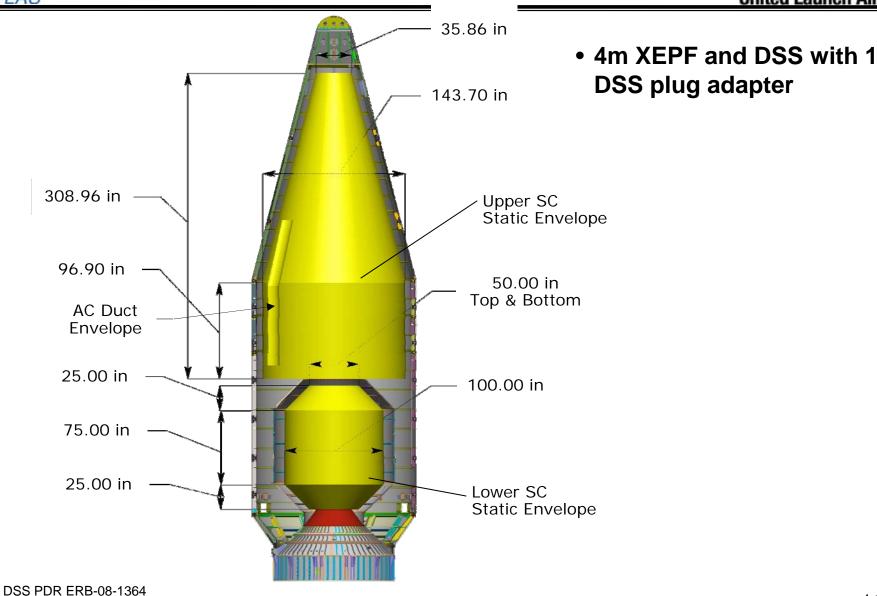




 4m XEPF and DSS with no DSS plug adapters

## **Payload Envelopes - Preliminary**

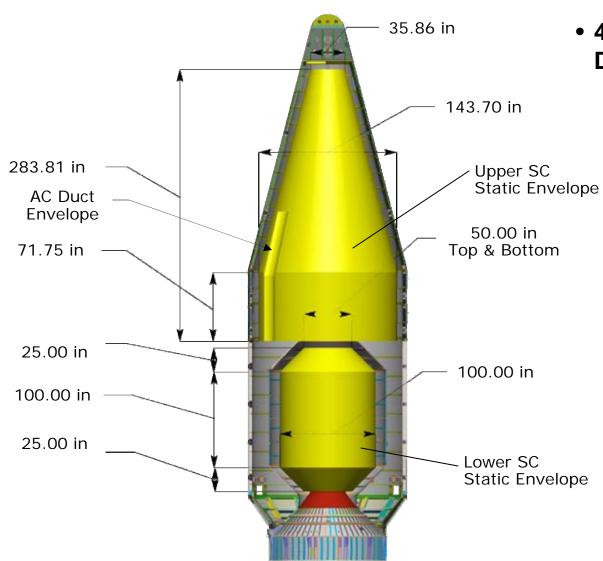




30 Sept 2008

## **Payload Envelopes - Preliminary**

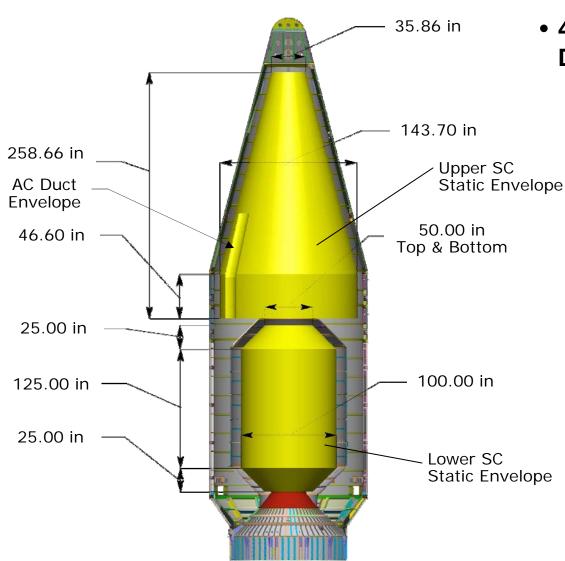




 4m XEPF and DSS with 2 DSS plug adapters

## **Payload Envelopes - Preliminary**

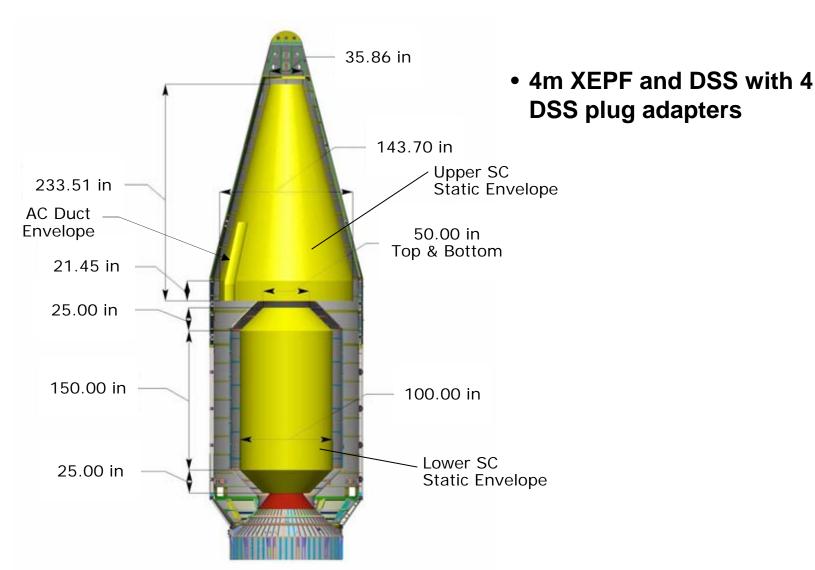




 4m XEPF and DSS with 3 DSS plug adapters

## **Payload Envelopes - Preliminary**











### Section 4.2

## **Loads & Dynamics**

Eric Johnson





- System Specification Requirements Loads
- Loads System Specification Requirements Verification
- Space Vehicle Interface Requirements (SVIR) Requirements Loads
- Loads SVIR Requirements Verification
- 58-00808 Design Requirements Document (DRD) Requirements and Verification

  Loads
- Requirements Verification Summary
- Initial Coupled Loads Analysis (CLA-1)
- Second Coupled Loads Analysis (CLA-2) (In Work)
- Flight Instrumentation Plan and Proposed Dual Spacecraft System (DSS) Instrumentation (Low-Frequency Accelerometers Only)
- Risk
- Remaining Tasks (for December 2008 Engineering Review Board (ERB), Critical Design Review (CDR), and prior to Initial Launch Capability (ILC))
- Summary



## System Spec Requirements – Loads



•	3.1.1.2.3	Perform Jettison of Payload Fairing
•	3.2.1.3.1	Spacecraft Weight Ranges
•	3.2.2	Telemeter Key Data
	- 3.2.2.2	Post Flight Reconstruction Data
	- 3.2.2.3	Research and Development (R & D) Flight Instrumentation
•	3.7.1	Natural Environments
	- 3.7.1.4.1	Operational and Non-Operational Ground Winds
	- 3.7.1.5	Winds Aloft
•	3.7.2	Induced Environments
	- 3.7.2.2	Aerodynamic Loads
	- 3.7.2.3	Limit Loads Due to Environmental Transients
•	3.10.2	Stiffness and Deflections
•	3.10.4	Design Margins
	- 3.10.4.4	Launch Vehicle (LV) Sustained Accelerations



# Loads System Spec Requirements Verification



- 3.1.1.2.3 Perform Jettison of Payload Fairing (PLF)
  - No change to basic mechanics of payload fairing jettison
  - Only hardware change possibly affecting PLF jettison is addition of Environmental Conditioning System (ECS) inlet to lower Space Vehicle (SV) compartment with 'sleeve' joint between PLF and Dual Spacecraft System (DSS)
  - Verification is by analysis
  - Preliminary evaluation is that 'sleeve' joint and additional ECS inlet hardware will not materially affect PLF jettison
    - High margins; generous dispersion allowances
    - Evaluation will be revisited before first flight
- 3.2.1.3.1 Spacecraft Weight Ranges
  - No change; proposed Space Vehicle Interface Requirements (SVIR) requirement 3.2.11.2 states 'DSS with integrated spacecraft shall not exceed the payload mass properties as specified in the SVIR ... for an Atlas 400 series vehicle'.



## Loads System Spec Requirements Verification (continued)



- 3.2.2.2 Telemeter Post Flight Reconstruction Data
- 3.2.2.3 Telemeter R & D Flight Instrumentation
  - For Loads: Additional low-frequency accelerometers to be provided at upper SV interface similar to those already located at aft SV interface (I/F) (on Centaur Forward Adapter (CFA))
  - Verification by inspection and analysis
  - Instrumentation options, including Loads, Shock, Vibe accels and acoustic microphones, discussed at System Requirements Review (SRR) and at subsequent meetings of loads, environments, avionics personnel
  - Instrumentation recommendations provided later in this section and in Section 5.3 (Vibro-Acoustics)
- 3.7.1.4.1 Operational and Non-Operational Ground Winds
  - Requirement is to withstand 85% ground wind
  - No change to outboard profile; no change to maximum SV (or SVs + DSS) weight requirement; no load path between DSS and PLF
  - DSS and its SVs drive no change in ground winds loads or loads margin verifications (by analysis)



## Loads System Spec Requirements Verification (continued)



- 3.7.1.5 Winds Aloft
  - Requirement is to withstand 85% wind aloft
  - No change to outboard profile; no change to maximum SV (or SVs + DSS) weight requirement; no load path between DSS and PLF
  - DSS, SVs drive no change in winds aloft loads or loads margin verifications (by analysis)
- 3.7.2.2 Aerodynamic Loads
  - Requirement is to withstand quasi-static (static-elastic) plus P99/90 (gust, buffet) aerodynamic loading
  - No change to outboard profile; no change to maximum SV (or SVs + DSS) weight requirement; no load path between DSS and PLF
  - DSS, SVs drive no change in quasi-static or aerodynamic loads or loads margin verifications (by analysis)
- 3.7.2.3 Limit Loads Due to Environmental Transients
  - Requirement is to withstand all dynamic transient loading
  - Standard development and mission integration coupled loads analyses verify requirement is satisfied (during design phase and for every mission)



## Loads System Spec Requirements Verification (continued)



- 3.10.2 Stiffness and Deflections
  - No contact between SV and LV except at interface attachments
  - Standard development and mission integration clearance loss analyses verify requirement is satisfied (during design phase and for every mission)
- 3.10.4.4 Launch Vehicle (LV) Sustained Accelerations
  - LV shall 'withstand and operate during and after exposure to sustained accelerations defined in TRD ...'
    - (TRD is Atlas V Technical Requirements Document)
  - Loads from sustained accelerations are added to (zero-mean) random vibration results
  - Low-frequency coupled loads analyses implicitly include sustained accelerations because all external forces are applied to LV, and response is not zero-mean
  - DSS, SVs drive no change to existing processes
  - Verification is by analysis



## **SVIR Requirements – Loads**



- 3.1.1.1.1 Atlas V 400 Series Launch Vehicle SV Envelopes
- 3.1.1.1.2 Payload Stay-Out Zones
- 3.1.1.2.3.1 Range of Payload Mass Properties
- 3.1.1.2.3.2 Atlas V 400 Series SV Structural Stiffness
  - 3.1.1.2.3.2.1 Atlas V 400 SV Interface Load
- 3.1.3.6 Acceleration Load Factors
- 3.1.5.3 Encapsulated Payload Hoist and Mate
  - 3.1.5.3.3 Hoist Accelerations
- 3.2.11.2 Integrated DSS Mass Properties



# Loads SVIR Requirements Verification



- 3.1.1.1.1 Atlas V 400 Series Launch Vehicle SV Envelope
  - ¶3.1.1.1.1.1 defines 400 Series SV dynamic envelope
    - Volume is defined to be 'representative', and mission-specific clearance loss analysis is final determination of acceptable clearance
    - Verification is by clearance loss analysis
  - ¶3.1.1.1.1.2 states Atlas V 400 shall accommodate ±36 inch payload volume cylindrical section length change from baseline
    - Extended Payload Fairing (EPF) is baseline; Large Payload Fairing (LPF) and eXtra-Extended Payload Fairing (XEPF) give ±36 inch change in length
    - LPF, EPF, XEPF may each be used with DSS
- 3.1.1.1.2 Payload Stay-Out Zones
  - DSS plus SVs drive no change in existing overall payload stay-out zones
  - DSS will define additional stay-out zones (e.g., for upper SV)
    - No change to process (still use LV/SV Interface Control Document (ICD) to define stay-out zones)
  - Verification is by clearance loss analysis



## Loads SVIR Requirements Verification (continued)



- 3.1.1.2.3.1 Range of Payload Mass Properties
  - DSS plus SVs is now considered to be 'payload'
    - New SVIR ¶3.2.11.2 states 'DSS with integrated spacecraft shall not exceed the payload mass properties as specified in the SVIR, paragraph 3.1.1.2.3.1 ...'
  - Verification is by mass properties and coupled loads analyses



## Loads SVIR Requirements Verification (continued)



- 3.1.1.2.3.2 Atlas V 400 Series SV Structural Stiffness
  - Defines minimum frequency guidelines
  - Verification is by coupled loads analysis and clearance loss analysis
  - 3.1.1.2.3.2.1 Atlas V 400 SV Interface Load
    - 'Atlas V 400 shall have sufficient strength to withstand interface loads imparted by the SV with weight and center of gravity location per paragraph 3.1.1.2.3.1, Figure 3.1.1.2.3-1, and structural stiffness per paragraph 3.1.1.2.3.2'
    - Verification is by coupled loads analysis and stress analysis
- 3.1.3.6 Acceleration Load Factors
  - Requirement provides load factors for preliminary design, to be superseded by coupled loads analysis results
  - Verification is by coupled loads analysis



## Loads SVIR Requirements Verification (continued)



- 3.1.5.3 Encapsulated Payload Hoist and Mate
  - 3.1.5.3.3 Hoist Accelerations
    - Requirement specifies maximum encapsulated payload hoist acceleration limits
    - Verification is by hoist coupled loads analysis and clearance loss analysis
- 3.2.11.2 Integrated DSS Mass Properties
  - New SVIR requirement specifically for DSS
  - 'DSS with integrated spacecraft shall not exceed the payload mass properties as specified in the SVIR, paragraph 3.1.1.2.3.1 ...'
  - Verification is by mass properties and coupled loads analyses



# 58-00808 DRD Requirements and Verification—Loads



- 3.2.4.3.9.3.2 DSS CG offset from LV centerline shall be no more than [1.0 inch] (Upper (separable) part of DSS only)
  - Verification is by mass properties and loads analyses
    - Early loads analyses included c.g. offset >1.0 inch on entire DSS (DSS only, not including SVs) (conservative)



## **Requirements Verification Summary**



- All loads and clearance loss requirements are verified by Analysis (A)
- Instrumentation requirements are verified by Inspection and Analysis (I and A)
- Many of the requirements are verified for each mission as part of standard mission integration analyses
  - Coupled Loads Analysis (CLA) Several cycles
  - Clearance Loss Analysis using mission-specific critical clearance locations and mission-specific dynamic analysis results
- Initial design development loads and dynamic clearance loss analyses are complete
  - LMA-AD-TTR-08-058, 15 April 2008
    - 'Zero-plug' DSS, 10k lbm 'indicator payload' SV in upper position, 5k lbm 'indicator payload' SV in lower position
      - 'Indicator payloads' discussed in more detail on subsequent charts
    - 411/XEPF, 431/XEPF liftoff
    - 431/XEPF airloads, maximum axial acceleration (max g), Booster Engine Cutoff (BECO), Centaur Main Engine Cutoff 2 (final Centaur engine shutdown) (MECO2)
    - 401 and 431 autopilot modes supplied to Flight Controls
    - Loads and dynamic clearance losses computed
    - Conservative analysis; reasonable and acceptable results



# Requirements Verification Summary (cont.)



- Second loads analysis (CLA) in work
  - 'Four-plug' DSS, two 'real' SVs
  - Analysis events and data recovery similar to first CLA
    - LV loads, dynamic clearance losses
    - Autopilot modes completed and supplied to Flight Controls
  - Ref: ULA-AD-TTR-08-151 (CLA 'kickoff' TTR) (20 August 2008)
  - Scheduled complete 18 November 2008
- Expect to have Engineering Review Board (ERB) covering loads analyses, structural margins, autopilot stability and margins after second CLA and margins evaluation are complete (~December 2008)



## **Initial Loads Analysis (CLA-1)**

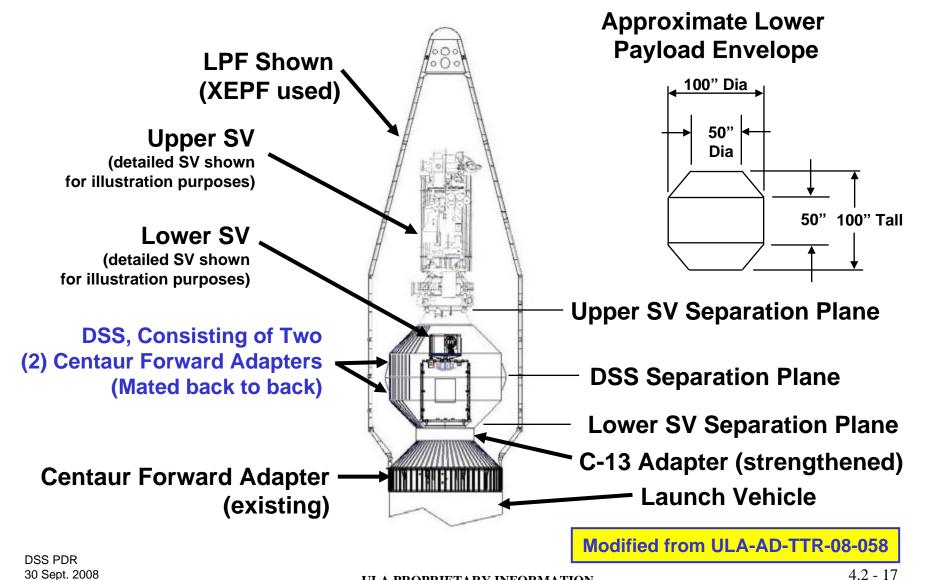


- (ref: ULA-AD-TTR-08-002r1, 10 Jan 2008, ULA-AD-TTR-08-058, 15 April 2008)
- Configurations:
  - 411 / XEPF / DSS / SVs: Liftoff only
  - 431 / XEPF / DSS / SVs: Liftoff, Airloads (M0.6, M1.0, M1.2), Max g, BECO, MECO2
  - 401 / XEPF / DSS / SVs, 431 / XEPF / DSS /SVs: Autopilot modes
  - 'zero plug' DSS (CLA DSS weight 1020 lbm w/ two conical adapters and C13, vs. 1041.4 lbm estimated weight as of February 2008)
  - SVs were 'indicator payloads' (IPLs), 10k lbm upper, 5k lbm lower
    - IPL modal mass distribution is ~average of nine Atlas V SVs
    - Upper SV c.g. distance 70 in. from top of DSS
    - Lower SV c.g. distance 68.666 in. from top of Centaur Forward Adapter (CFA)
       (52 in. from top of lower SV conical payload adapter)
    - SV masses, c.g. distances chosen to be similar to design SV when combined with DSS mass, c.g. (DSS estimated 1300 lbm, c.g. 58.538 in. from top of CFA)
      - 'Similar' means having ~same compression line load at top of CFA with 6g axial, 2g lateral load factors
      - Design SV was 20 k lbm, c.g. 110 in. fwd of CFA
  - All configurations included Large Helium Bottles (LHBs), 400 series Interstage Adapter / Frangible Joint Assembly (400-ISA / FJA)



## CLA-1 Configuration





ULA PROPRIETARY INFORMATION



## **CLA-1 Inputs, SV 'Load Factor' Results**



- Damping: 1% of critical, with coupled damping for LHBs
- 1.25 dynamic uncertainty factor (DUF) applied to all results
- 431/XEPF 20k SV trajectory, 5g max nominal axial acceleration
- SV c.g. 'load factor' accelerations in g's:

			431/XEPF				
	411/XEPF	431/XEPF	Max				
	Liftoff	Liftoff	Airloads	Max g	BECO	MECO2	Envelope
Upper SV c.g. Axial Load Factor	1.72	2.20	1.90	6.70	6.62	1.40	6.70
Upper SV c.g. Lateral Load Factor	1.06	0.91	0.95	0.12	0.37	0.07	1.06
Lower SV c.g. Axial Load Factor	1.77	2.17	1.91	6.10	5.63	1.53	6.10
Lower SV c.g. Lateral Load Factor	0.81	0.80	0.89	0.19	0.33	0.16	0.89

- Responses are typical of those seen by Atlas V SVs
- Axial load factors can be reduced by tailoring trajectory
  - RD180 can be throttled back at some cost to performance

Modified from ULA-AD-TTR-08-058



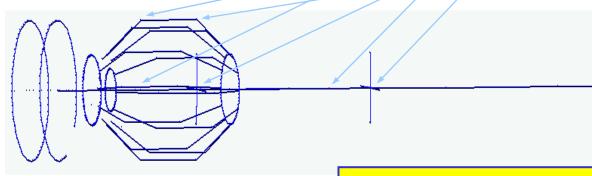
## CLA-1 Relative Displacement Results



### Relative displacements, inches:

Description	Dir.*	-411 XEP	F Liftoff	-431 XEF	PF Liftoff	Max Ai	irloads	Max	G	BE	CO	MECO	Absolute	RSS
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min		Maximum	(Lateral)
Upper SV to PLF: 89" fwd of I/F, Sta 2788	Χ	0.063	0.022	0.080	0.023	0.067	0.005	0.242	0.120	0.240	-0.063		0.242	
Upper SV to PLF: 89" fwd of I/F, Sta 2788	Υ	0.833	-0.922	0.814	-0.883	1.351	-1.477	0.026	0.014	0.393	-0.401		1.477	2.08
Upper SV to PLF: 89" fwd of I/F, Sta 2788	Z	1.162	-1.166	0.810	-0.821	1.443	-1.471	-0.005	-0.015	0.262	-0.259		1.471	
Upper SV to PLF: 125" fwd of I/F, Sta 2824	Х	0.063	0.022	0.080	0.023	0.067	0.002	0.241	0.119	0.239	-0.063		0.241	
Upper SV to PLF: 125" fwd of I/F, Sta 2824	Υ	0.985	-1.091	0.963	-1.045	1.582	-1.732	0.030	0.016	0.465	-0.475		1.732	2.45
Upper SV to PLF: 125" fwd of I/F, Sta 2824	Z	1.375	-1.380	0.959	-0.972	1.694	-1.727	-0.006	-0.018	0.310	-0.307		1.727	/
Lower SV to DSS aft cone/cyl jct, Sta 2619	Х	-0.009	-0.025	-0.010	-0.031	-0.018	-0.027	-0.047	-0.095	0.025	-0.094	0.010 -0.020	0.095	
Lower SV to DSS aft cone/cyl jct, Sta 2619	Υ	0.097	-0.088	0.093	-0.086	0.099	-0.084	-0.001	-0.006	0.044	-0.043	0.007 -0.008	0.099	0.14
Lower SV to DSS aft cone/cyl jct, Sta 2619	Z	0.124	-0.124	0.088	-0.088	0.102	-0.101	0.002	-0.003	0.029	-0.029	0.003 -0.003	0.102	
Lower SV to DSS fwd cone/cyl jct, Sta 2669	Х	-0.010	-0.026	-0.010	-0.033	-0.019	-0.029	-0.051	-0.102	0.026	-0.101	0.011 -0.022	0 102	
Lower SV to DSS fwd cone/cyl jct, Sta 2669	Υ	0.233	-0.209	0.223	-0.206	0.236	-0.202	-0.001	-0.013	0.104	-0.102	0.018 -0.018	0.236	0.34
Lower SV to DSS fwd cone/cyl jct, Sta 2669	Z	0.292	-0.293	0.209	-0.207	0.241	-0.238	0.007	-0.007	0.068	-0.068	0.006 -0.006	0.241	
DSS aft cone/cyl jct to PLF, Sta 2619	Х	-0.016	-0.044	-0.016	-0.057	-0.002	-0.048	-0.086	-0.170	0.043	-0.168		0.170	
DSS aft cone/cyl jct to PLF, Sta 2619	Υ	0.170	-0.155	0.163	-0.151	0.339	-0.318	-0.002	-0.007	0.073	-0.072	1 / /	0.339	0.47
DSS aft cone/cyl jct to PLF, Sta 2619	Z	0.215	-0.215	0.150	-0.149	0.331	-0.325	0.004	-0.001	0.047	-0.048		0.331	
DSS fwd cone/cyl jct to PLF, Sta 2669	Х	-0.016	-0.046	-0.017	-0.058	0.001	-0.049	-0.087	-0.175	0.045	-0.172	1	0.175	
DSS fwd cone/cyl jct to PLF, Sta 2669	Υ	0.388	-0.352	0.372	-0.343	0.667	-0.615	-0.006	-0.016	0.168	-0.165		0.667	0.93
DSS fwd cone/cyl jct to PLF, Sta 2669	Z	0.488	-0.487	0.342	-0.339	0.655	-0.644	0.007	-0.002	0.108	-0.109		û.655	

<sup>\*</sup> CCB Rectangular Corrdinates; X is Positive Fwd

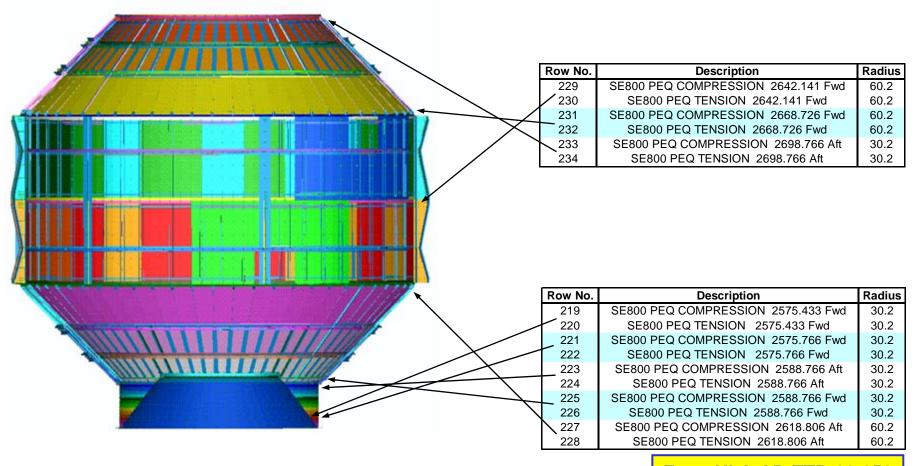


**Modified from ULA-AD-TTR-08-058** 



## CLA-1 Section Load Key





DSS PDR 30 Sept. 2008 From ULA-AD-TTR-08-058



## **CLA-1 Section Load Results**



- Effect of 5 inch SV cg offset added to Peq results
  - Assumed both upper and lower offsets in same direction
  - Max lateral offset per EELV Standard Interface Specification (SIS), version 6, para. 3.1.6.1

Row No.	Description	Radius	-411	-431	Max Air	Max G	BECO	MECO	Envelope
			Liftoff	Liftoff					
157	SE540 PEQ COMPRESSION 2545.06 Fwd	60.2	-80174	-75055	-78213	-128956	-147001	-24002	-147001
160	SE540 PEQ TENSION 2545.06 Fwd	60.2	37630	26703	25110	-42300	62604	10969	62604
161	SE540 PEQ COMPRESSION 2574.34 Fwd	31.0	-119052	-108042	-110614	-140435	-171195	-26960	-171195
162	SE540 PEQ TENSION 2574.34 Fwd	31.0	79203	62209	60813	-19982	93307	15985	93307
219	SE800 PEQ COMPRESSION 2575.433 Fwd	30.2	-30496	-34692	-32038	-66199	-67035	-15698	-67035
220	SE800 PEQ TENSION 2575.433 Fwd	30.2	19391	21067	16219	15538	42606	13373	42606
221	SE800 PEQ COMPRESSION 2575.766 Fwd	30.2	-113794	-101973	-102251	-109235	-141763	-23235	-141763
222	SE800 PEQ TENSION 2575.766 Fwd	30.2	86819	72187	68403	784	90668	14633	90668
223	SE800 PEQ COMPRESSION 2588.766 Aft	30.2	-108169	-97554	-97539	-108605	-139186	-23130	-139186
224	SE800 PEQ TENSION 2588.766 Aft	30.2	81384	67961	63925	906	88032	14648	88032
225	SE800 PEQ COMPRESSION 2588.766 Fwd	30.2	-108138	-97516	-97498	-108464	-139054	-23121	-139054
226	SE800 PEQ TENSION 2588.766 Fwd	30.2	81411	67990	63956	1007	88014	14664	88014
227	SE800 PEQ COMPRESSION 2618.806 Aft	60.2	-55338	-53644	-53006	-88677	-103377	-18720	-103377
228	SE800 PEQ TENSION 2618.806 Aft	60.2	29079	23977	20072	-16874	50184	10779	50184
229	SE800 PEQ COMPRESSION 2642.141 Fwd	60.2	-50222	-49827	-48711	-87748	-100574	-18522	-100574
230	SE800 PEQ TENSION 2642.141 Fwd	60.2	24344	20513	16254	-16189	47875	10852	47875
231	SE800 PEQ COMPRESSION 2668.726 Fwd	60.2	-44597	-45723	-43915	-86755	-97401	-18281	-97401
232	SE800 PEQ TENSION 2668.726 Fwd	60.2	19158	16849	12044	-15302	45393	10961	45393
233	SE800 PEQ COMPRESSION 2698.766 Aft	30.2	-62566	-64711	-59284	-104623	-117437	-21883	-117437
234	SE800 PEQ TENSION 2698.766 Aft	30.2	37747	36421	28021	4501	67485	15251	67485

\*Centaur equipment module loads

From ULA-AD-TTR-08-058



# **CLA-1 Results Discussion**



- DSS loads are within capability (ref: PDR Section 4.3)
- Autopilot stability margins OK (ref: PDR Section 5.8)
- Most of equivalent axial load (Peq) envelope is from BECO
  - ~75% 80% from nominal shutdown, of which ~70% 80% is from axial response
  - Axial response may be reduced by max g limiting
    - Some performance reduction
  - BECO responses may be reduced by splitting LO2 feedline 'waterhammer' response from early max axial acceleration
    - This is a BECO improvement task in work (for all Atlas V)
- Relative displacements calculation is conservative because is root-sum-square (RSS) of two lateral component maxima
  - Time-consistent RSS could be done (more effort)



# CLA-2 (In Work)



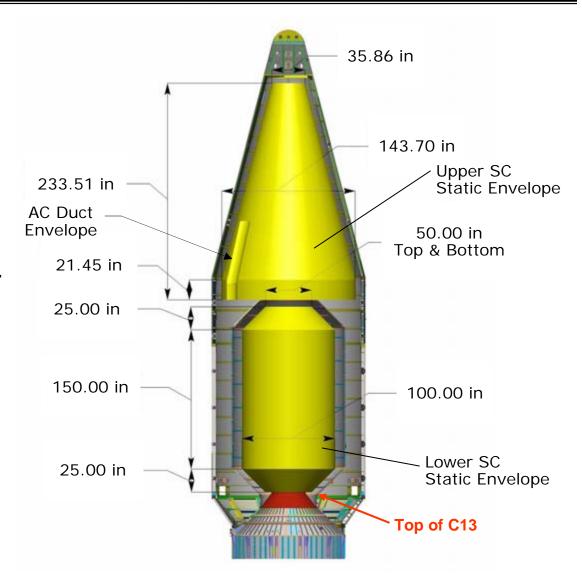
- (ref: ULA-AD-TTR-08-151, 20 August 2008)
- Same combinations of 4nx vehicles, PLFs, events as CLA-1
  - 411 / XEPF / DSS / SVs: Liftoff only
  - 431 / XEPF / DSS / SVs: Liftoff, Airloads (Mach 0.6 (M0.6), M1.0, M1.2), Max g, BECO, MECO2
  - 401 / XEPF / DSS / SVs, 431 / XEPF / DSS /SVs: Autopilot modes
  - 'Four-plug' DSS
    - Weight 1562 lbm vs. 1495 lbm from design estimate (both with lower conical payload adapter (PLA) only)
  - Upper and Lower SVs are Delta II-class spacecraft
    - SVs are not a 'real' mission configuration; are only to get 'typical' SVs into analysis
  - All configurations included Large Helium Bottles (LHBs),
     400 series Interstage Adapter / Frangible Joint Assembly (400-ISA / FJA)



# CLA-2 Configuration



- Standard DSS aft PLA is shown in dark red
  - SV I/F dia. ~37 in.
  - Top of aft PLA is
     Sta. 2592.052
- Top of C13 is at Sta. 2588.766
  - Bolt circle 62.01 in.
- Payload volumes shown; four-plug DSS is visible
- (Figure is from SRR, Section 1.0)





# **CLA-2 Inputs**

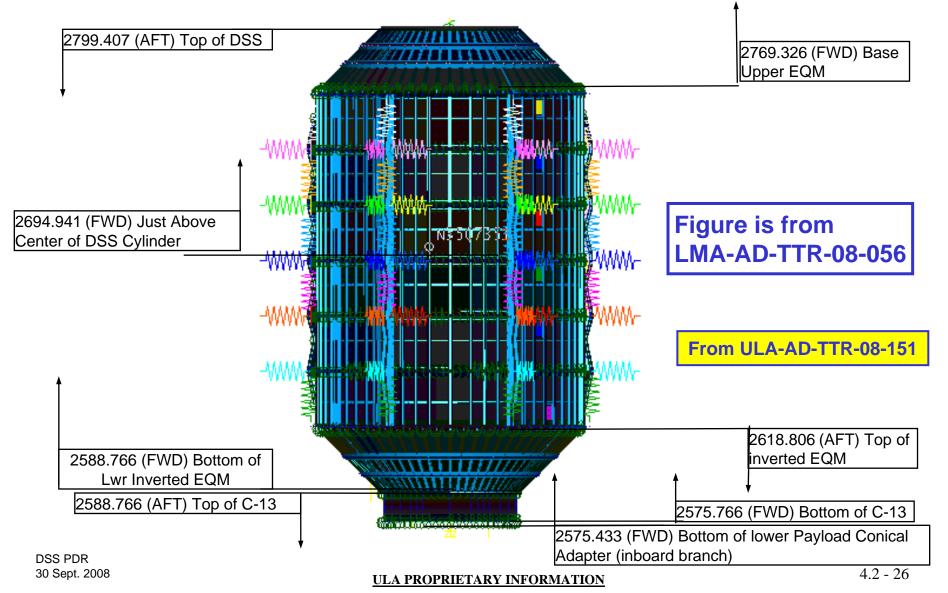


- Damping: 1% of critical, with coupled damping for LHBs
- 1.25 dynamic uncertainty factor (DUF) applied to all results
- 431/XEPF 20k SV trajectory, 5g max nominal axial acceleration
- (All above inputs are same as for CLA-1)



# CLA-2 Section Load Key







# CLA-2 Analysis Schedule



ID	_	Task Name	Duration	Start	Finish		September		October			1	November				
	0					8/17 8/24	8/31 9/7 9/14	4 9/21	9/28	10/5	10/12	10/19	10/26	11/2	11/9 11	/16 1	1/23
1	<b>■</b>	Process SV Dynamic Models	53 hrs	Wed 8/27/08	Thu 9/4/08	8/27	9/4										
2	<b></b>	Kickoff TTR	0 days	Wed 8/20/08	Wed 8/20/08	<b>♦</b> 8/20											
3	4	431/XEPF/DSS Autopilot Modes	18 hrs	Mon 9/8/08	Tue 9/9/08		9/89/9										
4	<del>-</del>	401/XEPF/DSS Autopilot Modes	18 hrs	Wed 9/10/08	Thu 9/11/08		9/109/11										
5	<del></del>	431/XEPF/DSS Liftoff	80 hrs	Fri 9/12/08	Thu 9/25/08		9/12	9	/25								
6	<del>-</del>	431/XEPF/DSS Airloads	80 hrs	Mon 9/8/08	Thu 9/18/08		9/8	9/18									
7	<b></b>	411/XEPF/DSS Liftoff	53 hrs	Thu 10/23/08	Thu 10/30/08						10	/23	_1	0/30			
8	<b></b>	431/XEPF/DSS Max g	36 hrs	Thu 10/16/08	Wed 10/22/08					10	/16	_10	/22				
9	4	431/XEPF/DSS BECO	53 hrs	Thu 10/23/08	Thu 10/30/08						10	/23	1	0/30	7		
10	4	431/XEPF/DSS MECO2	44 hrs	Mon 11/3/08	Fri 11/7/08								11/3		1/7		
11	4	Document Results, Prepare for TTR	54 hrs	Mon 11/10/08	Tue 11/18/08									11/10		11/18	
12	4	Loads Analysis Results TTR	0 days	Tue 11/18/08	Tue 11/18/08											11/1	8

- Kickoff TTR 20 August 2008
- Autopilot modes completed 12 September 2008
- Analyses with expected most critical 'equivalent axial' and shear loads completed 25 September 2008 (431 liftoff, airloads)
  - Max g should give highest SV c.g. equivalent load factor, and is scheduled complete 22 October 2008
- 'Gap' in schedule is due to other work commitments
- Loads analysis complete 07 November 2008
- TTR, documentation complete 18 November 2008
- Flight Controls, Stress evaluations to follow
- ERB to present and approve loads, flight controls, stress results planned for December 2008



# **CLA-2 Interim Results**



- As of PDR, CLA-2 Liftoff, Airloads, Autopilot Modes completed
- All results are preliminary and have not been through the standard Mission Integration CLA review process
- DSS loads within capability (see PDR Section 4.3)
- Autopilot stability margins OK (see PDR Section 5.8)
- Final CLA-2 internal 'tabletop' review (TTR) scheduled for 18 Nov 2008
- ERB to discuss loads, structural margins, autopilot margins results to be scheduled for Dec 2008



# Flight Instrumentation Plan



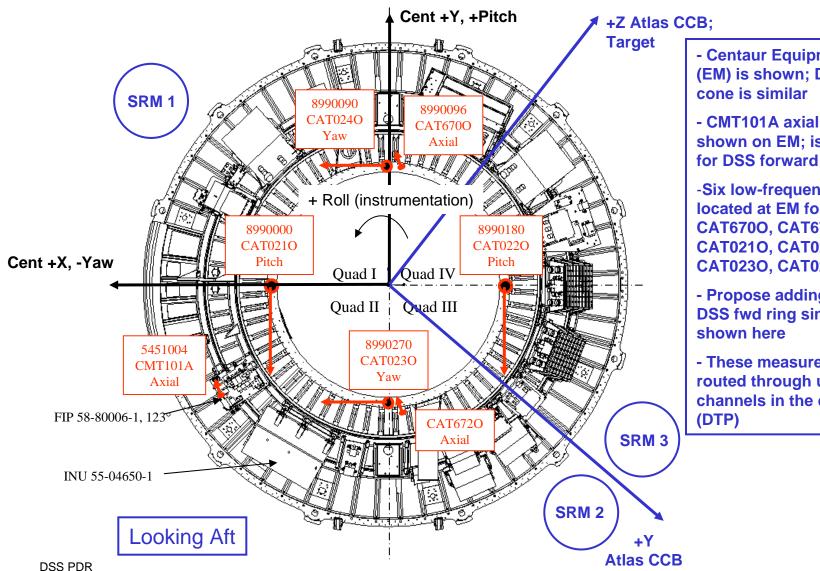
- Proposed loads, shock, vibration, acoustics flight instrumentation defined at SRR
  - Two options presented:
    - Recommended: Standard 4m PLF NASA R&D suite ('Mission Satisfaction Kit' – MSK) plus 22 additional channels
      - Requires additional 'digital telepak' (DTP) to accommodate bandwidth
    - Minimum: R & D 'Mission Satisfaction' suite plus two acoustic, three vibe measurements, up to six additional low-frequency accels
      - Additional acoustic, vibe measurements would 'fill up' existing DTP, assuming NASA standard 'Mission Satisfaction Kit' is included
- 18 September 2008 meeting of acoustics, shock, vibe, loads, and avionics personnel revised SRR-proposed instrumentation
- Further detail shown on following slides (low-frequency acceleration measurements only)
  - High-frequency random vibration, shock, and acoustics measurements covered in Section 5.3 (Vibro-Acoustics)



30 Sept. 2008

## **Proposed DSS Instrumentation Package** (Low-Frequency Accelerometers Only)





- CMT101A axial accelerometer shown on EM; is not proposed for DSS forward cone
- -Six low-frequency accels are located at EM forward ring: CAT670O, CAT672O axial; CAT021O, CAT022O pitch: **CAT023O, CAT024O yaw**
- Propose adding six accels to DSS fwd ring similar to those
- These measurements will be routed through unused 2kHz channels in the digital telepak





- Risk of exceeding DSS structural capability Low
  - DSS is assembled from parts already qualified to higher loads than are seen in DSS
  - Loads peaking issues at attachment / separation bolts considered to be low risk
- Risk of exceeding CFA structural capability Low
  - DSS and its SVs (together) are consistent with existing 400 series SV maximum weight and c.g. requirements
    - DSS is not likely to be critical; CFA or other Centaur or adapters structures are likely to be critical
  - Have already analyzed 'zero-plug' DSS configuration with 'indicator' SVs sized and with c.g. locations ~equivalent to maximum single SV weight, c.g. distance
  - Currently analyzing 'four-plug' DSS configuration with 'real' SVs (but not 'real' mission configuration)



# Risk (continued)



- Risk of excessive dynamic clearance losses Low
  - Clearance loss analysis done as standard part of integration cycle for every mission
  - First CLA's clearance loss results were reasonable and within expectations
  - As more DSS / SV configurations are analyzed, may revise upper SV dynamic envelope to reflect clearance loss analysis results
- Risk of adversely affecting PLF jettison clearances or margins Low
  - Only change affecting PLF jettison is addition of lower compartment ECS fitting and slip joint at duct
  - Check of PLF jettison inputs and margins indicates large margins exist to accommodate ECS fitting and duct



# **Remaining Tasks**



- Prior to December ERB
  - Complete second DSS/SV CLA; supply results to Stress and Flight Controls
  - Stress: Complete structural margins check
  - Flight Controls: Complete autopilot stability and margins checks
- Prior to CDR
  - Goal: Complete additional CLAs to evaluate loads and clearance loss sensitivities to DSS configuration and SV properties
  - Complete transport and hoist loads and clearance loss analyses and margins assessments



# **Remaining Tasks (continued)**



- Prior to ILC
  - Complete ILC mission-specific CLAs, including LV loads and LV/SV dynamic clearance losses
  - Structures: Complete mission-specific clearance loss analysis, including dynamic clearance losses (from CLA), manufacturing and assembly tolerances, etc.
  - Stress: Complete mission-specific structural margins check using CLA loads results
  - Flight Controls: Complete mission-specific autopilot stability and margins checks using mission-specific autopilot modes generated by Loads





- Initial CLA, structural margins, and autopilot margins assessments complete
  - Based on zero-plug DSS, max weight/c.g. 'indicator' SVs
- Second CLA with 'four-plug' DSS, 'real' SVs in work
  - ECD November 2008
  - Results and margins to be discussed at ERB ~Dec 2008
- Risks of unacceptable loads or clearance losses considered to be low

#### **Ready To Proceed to CDR**







### **Section 4.3**

### **Preliminary Stress Analysis**

S. Chan





- DSS System Requirements
- Preliminary Margin of Safety
- Summary



# **DSS System Design Requirements**



- There shall be no structural changes aft of the CFA interface, and all loads and Factors of Safety shall be within current design limits.
- DSS shall have a minimum design Factor of Safety of 1.25 for existing structures, and new features shall be designed to a Factor of Safety of 2.0 or 1.25 if tested.
- No full scale Structural test for the DSS.



# **DSS Indicator Payload Peq Comparison**



	Compression Peq	CLA Max Comp Peq	
Structure	Tested Value (Kips)	For 0 Plug Configuration	Margin of Safety (FS=1.25)
Structure	(IXIPS)	Configuration	(1 0-1.23)
DSS Plug	-544.0	-87.7	+3.96
DSS Conic	-402.4	-107.8	+1.98

	Tension Peq	CLA Max Tens Peq	
Structure	Tested Value (Kips)	For 0 Plug Configuration	Margin of Safety (FS=1.25)
DSS Plug	218.0*	34.5	+4.05
DSS Conic	343.1	72.8	+2.77

<sup>\*</sup> Expect to decrease due to reduced number of separation fittings.



# **CFA Indicator Payload Peq Comparison**



VS 2574.34 Fwd (Top of CFA)

		CLA Max Peq	
CFA	Tested Peq Value (Kips)	For 0 Plug Configuration	Margin of Safety (FS=1.25)
Compression	-402.4	-140.8	+1.28
Tension	343.1	70.8	+2.87



# **Summary**



- Preliminary results shows high margins for the DSS with indicator payloads for the 0 plug configuration.
- Preliminary evaluation of the 4 Plug configuration CLA shows load levels to be acceptable. (Not all flight cases completed at this time)
- Additional analysis required for new components (Ring Frame and Separation Fitting) to establish allowable using Factor of Safety of 2 or 1.25 if tested.

### Ready To Proceed to CDR







#### Section 5.1

### **Flight Design**

**Gary Myers** 





- Atlas V System Specification (11000-98-022) Requirements
- Atlas V Space Vehicle Interface Requirements (SVIR) (11000-98-023)
- Proposed SVIR Addenda
- Remaining Tasks
- Summary





- 3.1.1.2.4 Perform Upper Stage Flight
- 3.1.1.2.6 Perform Post-Sep Vehicle Disposal
- 3.1.1.5 Manage Payload Interface
- 3.1.1.6 Perform Navigation, Guidance and Control
- 3.2.1.3.2 Atlas V Performance Capability
- 3.2.1.5.1 Mission Required Margin Government Missions
- 3.2.1.5.2 Mission Required Margin Commercial Missions
- 3.2.Telemeter Key Data
- 3.2.2.1 Range Data
- 3.2.2.2 Post Flight Reconstruction Data
- 3.2.2.2.1 Link Margin
- 3.2.2.2.2 Telemetry Recovery
- 3.2.2.3 Research and Development Flight Instrumentation
- 3.2.2.4 Processing of Telemetry Data
- 3.2.3.4 Final Delivery to Orbit Maneuvers
- 3.2.3.5 Collision and Contamination Avoidance Maneuver (CCAM)
- 3.5.2 Orbital Debris





- 3.1.1.2.4 Perform Upper Stage Flight
  - The Launch Vehicle Segment shall start upper stage flight when the core booster has been successfully jettisoned and end when the payload has reached the injection orbit. This task includes upper stage main engine burns and coast flights. [57024,OT, A] [Approved]
- Compliance
  - DSS design affects vehicle performance capability, payload separation and post separation maneuvers which is mitigated though standard Mission Integration Analysis Tasks
    - Configuration, Performance, Weight and Status Report
    - Flight Performance Reserve Analysis
    - CCAM Analysis for Payload Injection
- Verification
  - Configuration, Performance, Weight and Status Report
  - Flight Performance Reserve Analysis
  - CCAM Analysis for Payload Injection
  - FASTER
- Risk
  - Low



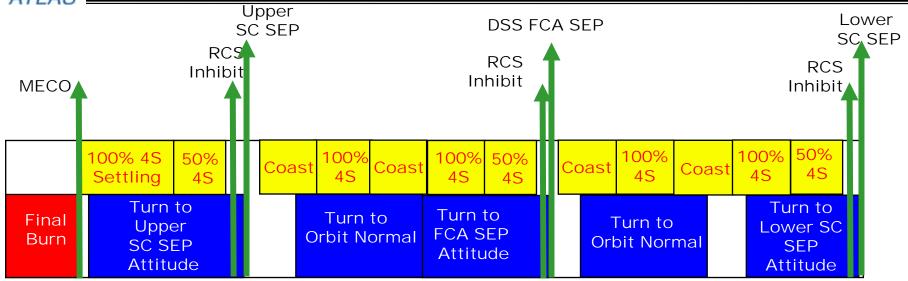


- 3.1.1.2.6 Perform Post-Separation Vehicle Disposal
  - The Launch Vehicle Segment shall perform a maneuver for postseparation disposal of the launch vehicle elements. This task includes de-spinning the upper stage if necessary, performing a contamination and collision avoidance maneuver and disposing of all propellants. [57026,OT, A] [Approved]
- Compliance
  - DSS design requires additional settling and maneuver to separate the FCA, reorientation for the Lower PL separation attitude, and overall design to preclude recontact of the FCA, Centaur, Upper and Lower PLs
    - Modified Baseline Post-Separation Sequence
    - CCAM Analysis
- Verification
  - FASTER
- Risk
  - Low

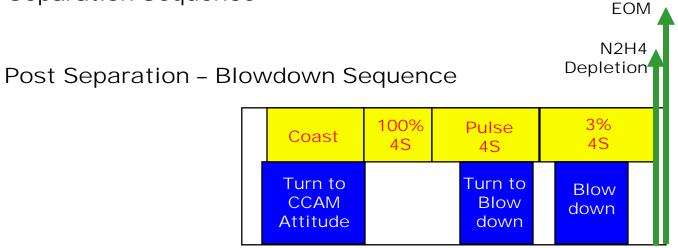


### **Baseline Post Separation Sequence**





Post Final MECO - Separation Sequence





# **Baseline CCAM Sequence**



USC_SEP+0	Upper Spacecraft Separation
USC_SEP+4	Start Turn to Orbit Normal
USC_SEP+300	Start Translation Burn 1
USC_SEP+370	End Translation Burn 1
USC_SEP+374	Turn to Minus Velocity Vector/Coast
USC_SEP+1870	Start Settling Burn 1
USC_SEP+2170	End Settling Burn 1
USC_SEP+2171	Separate Forward Canister Adapter (FCA)
USC_SEP+2175	Start Turn to Orbit Normal
USC_SEP+2475	Start Translation Burn 2
USC_SEP+2545	End Translation Burn 2
USC_SEP+2549	Turn to Minus Velocity Vector
USC_SEP+3175	Start Settling Burn 1
USC_SEP+3245	End Settling Burn 1
USC_SEP+3246	Lower Spacecraft Separation
USC_SEP+3250	Start Turn to Orbit Normal
USC_SEP+3550	Start Translation Burn 3
USC_SEP+3620	End Translation Burn 3
USC_SEP+3668	Start 5% Settling
USC_SEP+4236	Start 20% Settling
USC_SEP+4246	Start Turn to Blowdown Attitude
USC_SEP+4746	Start Blowdown

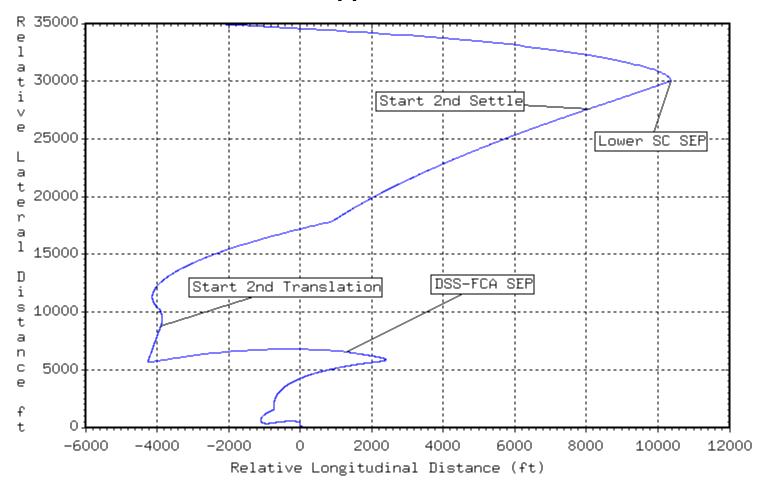
**DSS CCAM Sequence adds ~ 3200 sec to Centaur EOM** 



# **Baseline CCAM**



#### **Relative Distance of Upper SC to Centaur**

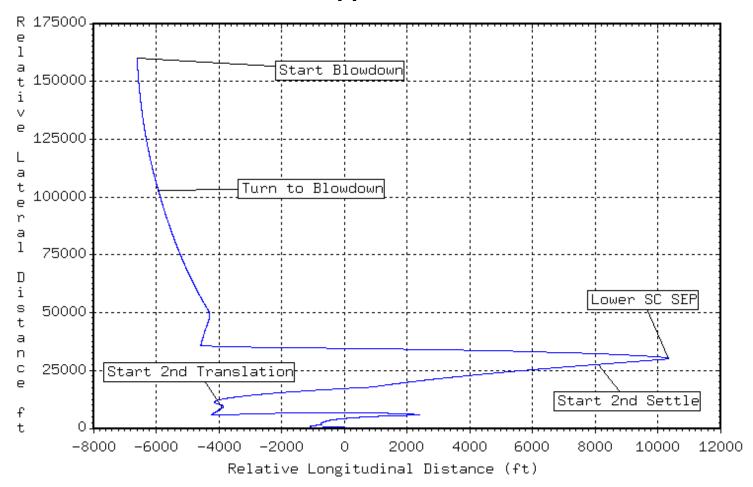




### **Baseline CCAM**



#### **Relative Distance of Upper SC to Centaur**







- 3.1.1.5 Manage Payload Interface
  - The Launch Vehicle Segment shall manage the interface between the launch vehicle and the payload. This includes the acquisition of telemetry from the payload for interleaving with launch vehicle data. This function ends with payload separation. [57029,OT, A] [Approved]
- Compliance
  - DSS design no impact
    - Separation of the FCA may be desired additional telemetry event recorded to the OPM and within existing capability
  - Due to the additional PL provided by the DSS and separation of the FCA, a standard Orbital Parameter Message (OPM) will include separation events with required telemetry for each PL
    - OPM Mission Peculiar
- Verification
  - Inspection
- Risk
  - Low





- 3.1.1.6 Perform Navigation, Guidance and Control
  - The Launch Vehicle Segment shall provide navigation, guidance and control capability. The flight computer estimates position and velocity based on translational acceleration and angular rotation measurements (navigation algorithms) and implements the trajectory profile including the roll, pitch and yaw program (guidance and control algorithms). [57030,OT, A] [Approved]
- Compliance
  - DSS affects only related to mass properties
    - Standard Trajectory Analysis products
  - FTINU provides actual sensed vehicle accelerations to Guidance Algorithms, which in effect would correct for any mass properties discrepancies
- Verification
  - FASTER
- Risk
  - Low





- 3.2.1.3.2 Atlas V Performance Capability
  - The Atlas V Launch Vehicle shall satisfy the performance requirements for the Design Reference Missions (DRMs) shown in Tables 3.2.1.3.2-1 through 3.2.1.3.2-18.
- Compliance
  - ULA-AFD-08-035, Version 08-01 Performance Capabilities Report, CDRL A-003, updates the Atlas V Performance Capability as listed in the System Specification.
  - The Atlas V current fleet performance relative to EELV design requirements as found in the System Performance Requirements Document (SPRD) and contracted commercial, NASA, DoD and NRO mission performance relative to current mission specific Interface Control Document (ICD) performance requirements
- Verification
  - Trajectory & Performance Analysis
- Risk
  - Low



# Atlas V Performance Capability CDRL A-003



#### **Table 1-1 SPRD Mission Model Lift Capability Requirements**

						Minimum
SPRD		Threshold Launch	Apogee	Perigee	Inclination	Vehicle
Mission	Reference Mission	Weight (lbs)	Altitude (n.mi.)	Altitude (n.mi.)	(deg)	Configuration
1	LEO	23,100	500	500	63.4	521
2	Polar 1	15,500	450	450	98.75	411
3	Polar 2	61,000	100	100	90	HLV
4	Semi-Sync Direct Inject	3,758	10,998	10,998	55	401
5	Semi-Sync Transfer 2	5,000	10,998	100	55	401
5a	Semi-Sync Transfer 1	5,000	10,998	100	39	401
6	GTO GTO	<del>26,100</del>	<del>19,324</del>	100	<del>27</del>	HLV
7	Molniya	7,000	21,150	650	63.4	401
8	GEO	13,500	19,323	19,323	0	HLV

Mission Model Lift Capability includes all SC chargeable weights, Upper SC, Lower SC and total DSS weight

Total DSS Weight: ~1009 lbm (DSS with Zero Plugs)

~1705 lbm (DSS with Four Plugs)

Ground ruled DSS Missions highlighted above (Total SPRD Req't Info Only)





- 3.2.1.5 Mission Margin
- 3.2.1.5.1 Mission Required Margin Government Missions
  - The Atlas V system shall provide a 3 sigma (99.865%) assurance of the vehicle fully meeting Government mission mass to orbit requirements (including performance margin capabilities) while considering possible uncertainties in Atlas V and environmental parameters such as propellant loading, Isp, and atmospheric density. [1231,OT, A] [Approved]
- 3.2.1.5.2 Mission Required Margin Commercial Missions
  - The Atlas V system shall provide a 2.33 sigma (99.0%) assurance of the vehicle fully meeting commercial mission mass to orbit requirements (including performance margin capabilities) while considering possible uncertainties in Atlas V and environmental parameters such as propellant loading, Isp, and atmospheric density. [60104,OT, A] [Approved]
- Compliance
  - Flight Performance Reserve Analysis determined by Reserve Analysis Program or Ideal Velocity (VIDEAL) equivalent per 2.33 or 3.0 sigma requirement, versus mission peculiar requirements
- Verification
  - Monte Carlo Analysis
- Risk
  - Low



### System Spec 11000-98-022 Requirements – Flight Design



- 3.2.2 Telemeter Key Data
  - The Atlas V systems will telemeter key data as defined below. [57056,OT, A] [Approved]
- 3.2.2.1 Range Data
  - The Launch Vehicle shall telemeter key data compatible with range equipment, to support range safety needs per EWR 127-1, as tailored. [12241,OT, A] [Approved]
- 3.2.2.2 Post Flight Reconstruction Data
  - The Launch Vehicle shall telemeter data required to assess launch vehicle performance, including identification of malfunction and failure causes, and assess the payload environment (mission satisfaction) from terminal count through disposal operations. [12242,OT, A] [Approved]
- 3.2.2.2.1 Link Margin
  - The Atlas V systems shall have positive Link Margin during the following critical events: main engine burns (including engine chill), pyro events, and SV separation event including CCAM. [57062,OT, A] [Approved]
- 3.2.2.2.2 Telemetry Recovery
  - The Launch Vehicle shall be capable of transmitting key data realtime as well as storing and telemetering key data at a later time to cover periods of inadequate link margin during mandatory periods through the completion of CCAM and disposal operations. [1238,OT, A] [Approved]
- Compliance
  - Centaur required maneuvers and settling for separation of the ACA must be performed to minimize impacts to RF Link Margin
  - Trajectory design Sequence of Events modified to provide DTP playback and Memory dump following Lower PL Separation
  - CCAM Analysis Mission Peculiar
  - RF Link Analysis Mission Peculiar analysis which is affected by orbital geometry, payload separation requirements
- Verification

Risk

- RF Link Analysis coordinated with Avionics and verified by the Range and IV&V for Government Missions
- CCAM Analysis verified by FASTER Testing

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\_ Low



### System Spec 11000-98-022 Requirements – Flight Design



- 3.2.3.4 Final Delivery to Orbit Maneuvers
  - The Atlas V upper stage shall comply with the final delivery to orbit maneuver requirements defined in the Space Vehicle Interface Requirements document, 11000-98-023. [59848,OT, A] [Approved]
- 3.2.3.5 Collision and Contamination Avoidance Maneuver (CCAM)
  - Following payload separation, the Launch Vehicle shall perform a contamination and collision avoidance maneuver (CCAM) to preclude recontact with the payload and to limit exposure of the payload to the contamination levels defined in the TRD, 11000-96-006. [1255,OT, A] [Approved]
- Compliance
  - Centaur required maneuvers and settling for separation of the ACA must be performed to minimize impacts to RF Link Margin
  - Trajectory design Sequence of Events modified to provide DTP playback and Memory dump following Lower PL Separation
  - CCAM Analysis Mission Peculiar
- Verification
  - CCAM Analysis verified by FASTER Testing
- Risk
  - Low



### System Spec 11000-98-022 Requirements – Flight Design



- 3.5.2 Orbital Debris
  - The Launch Vehicle shall comply with National, DOD, and USSPACECOM orbital debris minimization policies for safely disposing of or deorbiting Launch Vehicle stages. [1361,OT, A] [Approved]
- 3.5.2.2 Disposal Orbits
  - Launch Vehicle stages and other components left in orbit or allowed to decay naturally shall be initially placed in a disposal orbit consistent with the requirements defined in 3.2.3.5 for CCAM. [1362,OT, A] [Approved]
- Compliance
  - DSS FCA shall remain as orbital debris and unmitigated other than to preclude recontact with the Upper and Lower PLs and Centaur
  - FCA orbital debris is dependent upon the Upper and Lower PL mission & orbital requirements, and Centaur available propellants
    - FCA orbital debris can generally be assumed to stay in orbit longer than Centaur
    - Debris in GTO is expected to re-enter < 25 years
  - CCAM Analysis to predict FCA orbital debris state
  - Orbital Lifetime assessment for debris with 25 year or less to reentry
- Verification
  - Currently IV&V for Government Missions; however, commercial missions can be expected to be assessed
- Risk
  - Low



# **SVIR 11000-98-023 – Flight Design**



- 3.1.2.5.3.6 State Vector Data
- 3.1.2.5.3.6.1 State Vector Data for Multiple Payloads
- 3.1.4.2 Final Orbit
- 3.1.4.2.1 Separation Orientation, Accuracy and Stability



### **SVIR 11000-98-023 – Flight Design**



- 3.1.2.5.3.6 State Vector Data
  - The Atlas V System shall telemeter the guidance system calculated state vector (which will include position and velocity) and attitude data at the time of separation detection; this data will be provided to the SV operators in as close to real-time as possible (with a maximum of 20 minutes) after receipt of data at the Atlas V System contractor's facility. [27084,OT, A]
- 3.1.2.5.3.6.1 State Vector Data for Multiple Payloads
  - For multiple spacecraft on a single launch vehicle, the Atlas V System shall telemeter the guidance system calculated state vector (which will include position and velocity) and attitude data at the time of separation detection for up to two separation events; this data will be provided to the SV operators in as close to real-time as possible (within a maximum of 20 minutes) after receipt of data at the Atlas V System contractor's facility. [63036,OT, A]
- Compliance
  - DSS design no impact
    - Separation of the FCA may be desired additional telemetry event recorded to the OPM and within existing capability
  - Due to the additional PL provided by the DSS and separation of the FCA, a standard OPM will include separation events with required telemetry for each PL, as specified
    - OPM Mission Peculiar, delivery per SV ICD requirements
- Verification
  - Inspection
- Risk
  - Low



# **SVIR 11000-98-023 – Flight Design**



- 3.1.4.2 Final Orbit
  - Final orbit parameters such as Design Reference Mission descriptions, SV separation weights and orbit accuracies are specified in the Atlas V System Specification. [59778,OT, A]
- 3.1.4.2.1 Separation Orientation, Accuracy and Stability
  - Prior to separation, the Atlas V System will be capable of pointing the upper stage/SV to any desired attitude and either minimize all rotation rates (3-axis stabilized missions) or provide a spin (spin-stabilized missions) about the longitudinal axis or transverse axis. [27123,OT, B]
- Compliance
  - DSS design requires additional pointing and maneuver for separation of FCA
  - Upper and Lower PL requirements affect trajectory design
  - Flight Design Trajectory Analysis and subsequent child requirements to 3.1.4.2 are performed via mission integration tasks
    - · Configuration, Performance, Weight and Status Report
    - Injection Accuracy Analysis
    - CCAM Analysis
- Verification
  - FASTER Testing
- Risk
  - Low



### Proposed Addenda to SVIR 11000-98-023 – Flight Design



- 3.2.11 Dual Spacecraft System (DSS) Carrier
- 3.2.11.1 Integrated DSS Mission Capabilities



### Proposed Addenda to SVIR 11000-98-023 – Flight Design



- 3.2.11 Dual Spacecraft System (DSS) Carrier
  - The Atlas V system shall provide a Dual Spacecraft System (DSS) carrier to carry two distinct payloads on compatible missions with an Atlas V 4XX with a LPF, EPF, or XEPF payload fairing from LC-41
- 3.2.11.1 Integrated DSS Mission Capabilities
  - The DSS with integrated spacecraft shall perform all mission functions within the performance specified in the Atlas V System Specification, paragraph 3.2.1.3.2, Atlas V Performance Capability, for the applicable Atlas V vehicle configuration.
- Compliance
  - Update the Atlas V Trajectory Simulation Data Book for system description, post-separation (Upper DSS PL) sequence, and maneuvers upon ATP
  - Update TRAJEX configuration data base for DSS upon ATP
- Verification
  - By Inspection
- Risk
  - Low





- Remaining Tasks
  - None for DSS Design
  - Add DSS update to Atlas V Trajectory Simulation Data Book upon ATP
  - Incorporate stage model definition files to TRAJEX input file configuration data base
  - Standard Mission Integration tasks are required for implementation of the DSS with Mission Specific SV ICDs





Baseline integration of DSS complete for Flight Design

### **Ready To Proceed to CDR**







#### Section 5.2

# Mission Integration/System Analysis Shock

Lauren Edgell



# **Topics**



- DSS and Atlas V System Requirements
- Compliance
- Verification Plan
- Summary





- SVIR Requirement
  - "The Launch Vehicle elements shall be designed to withstand shock environments as specified in the TRD, 11000-96-006."
- DRD Requirement
  - 3.2.4.3.9.5.3 DSS separation shock shall not exceed S/C or Centaur avionics allowables or as specified in TRD 11000-96-006.



### Compliance



- No impact to Launch Vehicle environments
  - Upper Canister Separation Shock
    - Canister Separation Shock levels at CEM will be no worse than current PLF Jettison Shock levels
      - Six bolts (vs. eight for PLF base)
      - Greater attenuation (distance and joints)
  - Upper SV Separation
    - No change from current Atlas single SV Separation
- No impact to Spacecraft environments
  - Upper Canister Separation Shock
    - Canister Separation Shock levels at Lower SV/Canister
       Interface will be no worse than current PLF Jettison Shock levels
      - Six bolts (vs. eight for PLF base)
      - Similar attenuation (distance and joints)
  - Upper SV Separation
    - Lower SV is far removed from Upper SV generated shock



# Verification



- Methodology
  - Formal Shock analysis to be performed using distance and joint attenuation from source shock
    - No system level shock test required
- ECD
  - Verification to be completed prior to CDR



### Summary



- All DSS-unique shock environments are bounded by existing requirements
- Verification to be completed prior to CDR

### **Ready To Proceed to CDR**







#### Section 5.3

# **Systems Analysis Vibro-Acoustics**

Ed Heyd



### **Vibro-Acoustics Overview**



#### Requirement

"The Atlas V systems shall be able to withstand and operate in the maximum estimated noise levels as defined in the SVIR ¶3.1.3.3"

#### **Compliance**

- Preliminary results from vibro-acoustic analyses indicate that requirements will be met with margin
- Results indicate some margin to Mission Planner Guide spacecraft average level

#### Risk

LOW vibro-acoustic risk relative to requirement



# **Vibro-Acoustics Verification**



#### **Approach**

- Develop numerical models for AV-004 and DSS topologies
- Determine model differences (using diffuse acoustic field excitation)
- Modify AV-004 flight data with model differences to generate DSS estimates

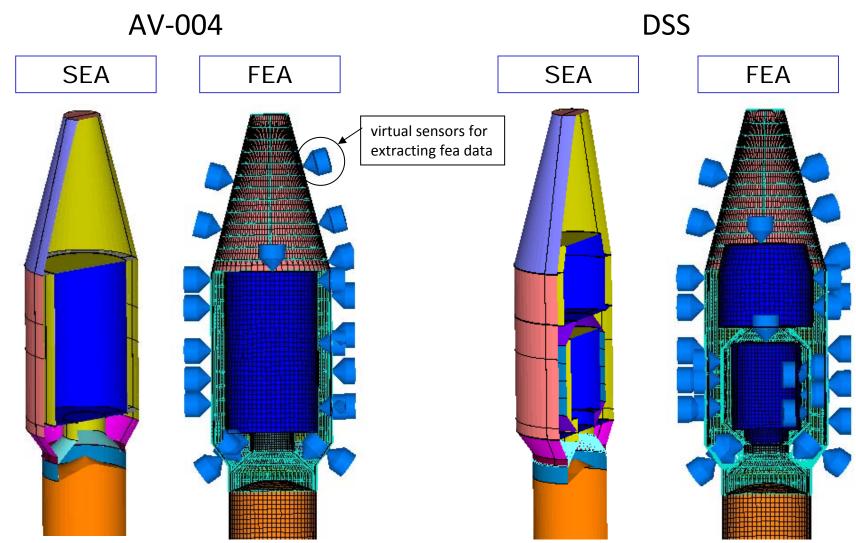
#### Numerical Models

- Modeled 'two plug' configuration as baseline
- Finite Element models generated for low frequencies (≤ 140 Hz)
- Statistical Energy models generated for high frequencies (> 140 Hz)
- Independent model reviews conducted



## **Vibro-Acoustic Models**



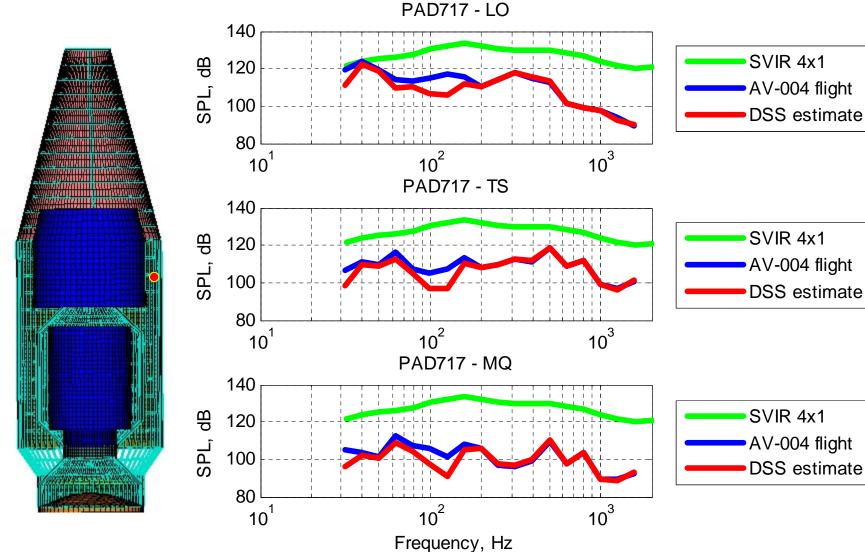


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### **DSS PAD717 Mic Estimate**

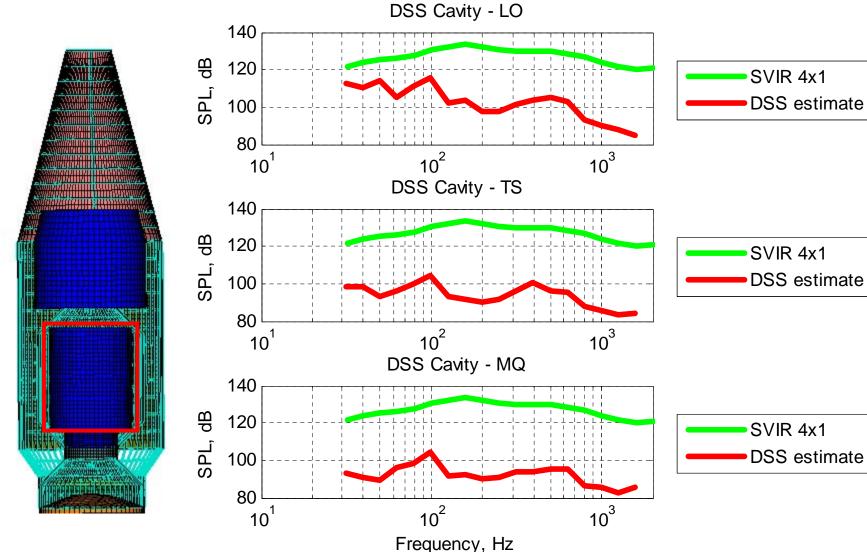






# **DSS Cavity Estimate**







### **Proposed Instrumentation Suite**



- Assume one DTP
- Existing MSK transducer locations in green
- New transducer locations in red
- Circles are microphones
- Squares are accelerometers

triaxial shock (8 kHz)

biaxial vibe (2 kHz)

microphone (8 kHz)

triaxial shock (8 kHz)

microphone (8 kHz)

triaxial vibe (2 kHz)

microphone (4 kHz)

microphone (8 kHz)

microphone (8 kHz)

biaxial vibe (2 kHz)

triaxial vibe (2 kHz)

microphone (4 kHz)



# **Vibro-Acoustics Summary**



- Remaining tasks prior to CDR
  - investigate impact of 'four plug' case on low frequency acoustic levels within the DSS canister
  - run final analyses based on refined designs, spacecraft estimates
  - refine instrumentation package based on model results

#### **Ready To Proceed to CDR**







#### Section 5.4

### **Aerophysics/Venting**

**Cindy Camp** 





- Requirements
  - Venting
  - Prelaunch ECS
  - Derived
- Remaining Tasks (for PDR, CDR and/or to ILC)
- Summary





- 3.1.3.7 PLF Pressure Decay Rate
  - 3.1.3.7.1 Atlas V 400 Pressure Decay Rates Payload Fairing internal pressure decay rates for Atlas V 400 shall be limited to 0.3 psi/sec except for 0.9 psi/sec for a maximum of five (5) seconds
  - Compliance shown by an integrated venting analysis
  - Preliminary results indicate proposed venting schematic (all holes sealed except in aft conical section) provides adequate venting for all configurations (DSS is freely vented) thus DSS internal pressure tracks PLF main volume pressure decay rates

	ı	
Number of CFA's	Number of stub adapters	Pressure Differential (psid)
2	2	1.09x10 <sup>-2</sup>
2	3	1.81x10 <sup>-2</sup>
2	4	2.72x10 <sup>-2</sup>
2	5	3.82x10 <sup>-2</sup>
2	6	5.10x10 <sup>-2</sup>





- 3.1.5.6.1.4 Supply Air Flow Velocity On The Launch Pad
  - PLF air/GN2 distribution system shall provide a maximum air flow velocity less than 32 fps for Atlas 400 in all directions. There will be localized areas of higher flow velocity at, near or associated with the air conditioning duct outlets
    - No specific requirements exist for lower spacecraft
    - Thermal Control indicates that requirements for lower DSS spacecraft will be secondary to the upper spacecraft
      - If upper SC wants inlet temperature of 60°F, than DSS lower spacecraft will get 60°F by default
  - Compliance shown by analysis
  - Gold pan diffuser design will minimize impingement velocities by forcing flow along DSS walls
  - Location of the DSS ECS should be in the top stub adapter to provide for the most efficient cooling of the DSS SC
  - All holes and vents must be sealed except in aft conic section and diaphragm between upper PLA and top conical section must be present
    - Prevents cross-contamination between upper and lower SC during prelaunch and ascent

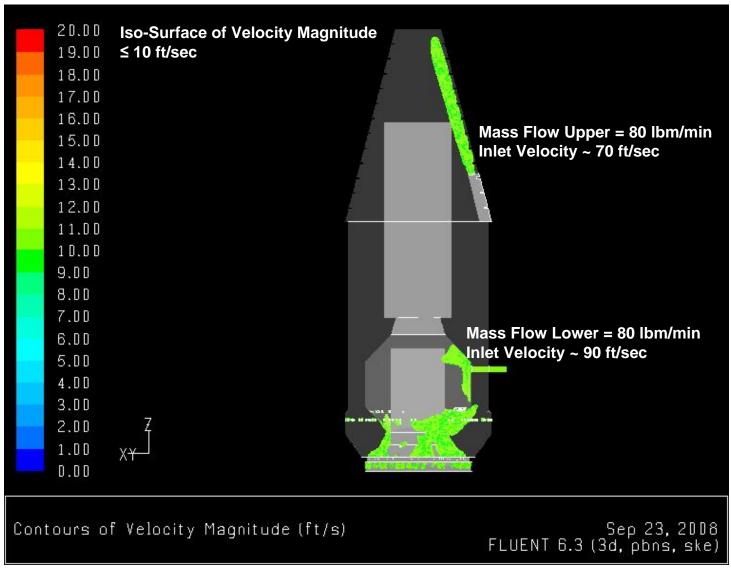




- 3.1.5.6.1.4 Supply Air Flow Velocity On The Launch Pad (continued)
  - Preliminary CFD analysis completed
    - Mass flow (160 lbm/min total) equally split between upper and DSS ECS
    - DSS inlet diameter = 6 inches
    - · Low fidelity grid
    - Zero plug configuration, modified goldpan diffuser in the top stub adapter indicate peak impingement velocities on DSS SC around 12 fps (with a 20% uncertainty factor)
    - Indicates adequate flow around all areas of lower spacecraft
    - Potential for upper spacecraft impingement exceeding 32 fps exists
      - Dependent on mass flow rate for upper ECS and SV envelope

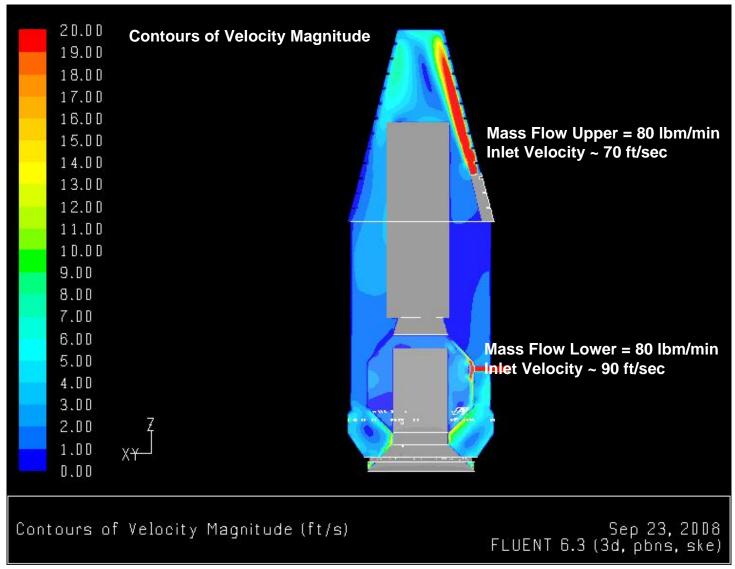






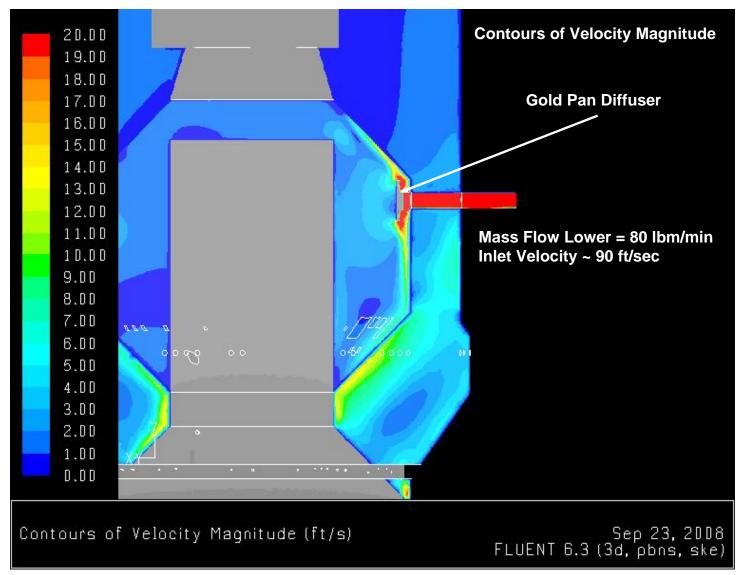






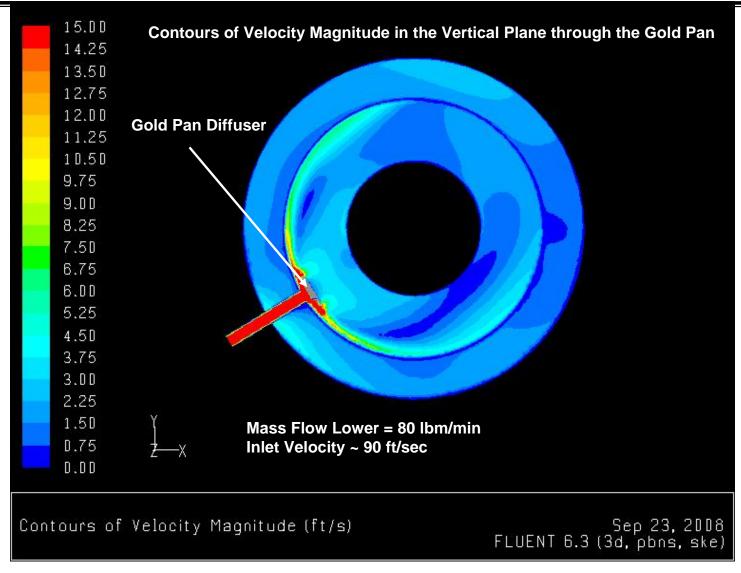














#### **Risk Items**



- Low technical risk for venting (depressurization rates and pressure differentials)
- Low technical risk for DSS ECS configuration
  - Preliminary CFD analysis indicates adequate flow dispersal and impingement velocities less than 32 ft/sec for lower spacecrafts at 80 lbm/min
- Low technical risk for impingement velocity for upper spacecraft
  - Dependent on maximum flow rate from upper ECS and spacecraft envelope
  - Various methods exist for mitigating potential exceedances of 32 fps
    - Flow rate reduction
    - Hardware modifications
    - Unique rotations of hardware





#### CDR

- Detailed integrated and coupled venting analysis completed for various configurations of the DSS in various versions of the PLF
  - Use typical trajectories
  - Use typical spacecraft geometries
- CFD with final inlet geometry and more representative spacecrafts

#### ILC

- Mission unique venting analysis
- Mission unique velocity impingement analysis



## **Summary**



- No issues or concerns with various configurations of the DSS
- Risk is slightly greater than low for upper ECS impingement actual requirements for mass flow rates and SV envelopes defined

#### **Ready To Proceed to CDR**







#### Section 5.5

#### **Thermal Control**

Mike Stitt





- Thermal Control groundrules for DSS
- Thermal Control groundrules for payloads
- Thermal Control requirements
- Verification of Thermal Control requirements
- Summary



### **Thermal Control Groundrules**



- ECS will be supplied to the DSS internal volume following PLF mate to the launch vehicle
- Reduction of Centaur avionics view factors to space due to DSS structure will not result in avionics temperature violations
- Separation systems will already be qualified (no Thermal Control design/qualification support needed)



### Thermal Control Groundrules for Payloads



- No lower ECS for DSS internal volume during transport/hoist
  - Canister will be purged with GN2 prior to transport to displace processing facility air and meet relative humidity requirements
    - Low flow rate GN2 purge will be initiated approximately 8 hours prior to transport
    - GN2 purge will be disconnected prior to transport (after upper ECS flow is established)
    - GN2 temperature inside canister will tend toward the gas temperature inside PLF
  - Gas temperature range for upper payload and payload inside canister during transport and hoist will be within Mission Planner's Guide range (40°F to 86°F)
    - A narrower gas temperature range for either payload will be considered mission unique



# Thermal Control Groundrules for Payloads, Continued



- Following mate, one spacecraft must be compatible with the prelaunch gas temperature and relative humidity environments that result from meeting gas conditioning requirements for the other spacecraft
  - Gas flow for upper and lower ducts is from the same ECS source (split flow)
  - No capability exists for different inlet gas temperature or dew point setpoints for each payload
  - Inlet gas temperature and dew point setpoints will be derived to meet internal PLF gas temperature and relative humidity requirements for one of the payloads
  - Other payload must be thermally compatible with resulting gas temperature and relative humidity environment
    - Gas temperature and relative humidity environments can be very different for upper and lower payload for a given ECS inlet temperature setpoint



# Thermal Control Groundrules for Payloads, Continued



 One payload must be compatible with flight thermal environments and timelines resulting from primary mission flight design and thermal requirements



#### **Thermal Control Requirements For DSS**



- GN2 purge for DSS internal volume is required prior to transport
- ECS for DSS internal volume is required following PLF mate to the launch vehicle until liftoff
- Thermal Control may need to specify surface coatings or MLI on external areas
  of the DSS to maintain component temperatures within allowable limits and
  provide a benign thermal environment for the internal payload
  - Separation system and/or connectors could require thermal control modifications
    - Modifications will minimize risk of regualification due to thermal reasons
  - Radiative environment for the internal payload must be considered when selecting external surface finishes for the DSS
    - External white paint on DSS currently meets this requirement
- Low emissivity surface finishes should be used on internal DSS surfaces to provide a benign radiative environment for the internal payload
  - Current baseline of Chem-film surfaces meet this requirement
  - Chem-film surfaces are low emissivity and will minimize radiative heat exchange between the DSS and lower payload



## Compliance



 Thermal Control requirements will be verified by integrated and component thermal analyses prior to the DSS CDR





 Thermal Control groundrules, requirements and verification plan have been identified

#### **Ready To Proceed to CDR**







#### Section 5.6

#### **Contamination Control**

David Zimmermann





- Documentation
- Hardware Cleanliness
- Materials
- Cross Contamination
- Summary



#### **Documentation**



- CONTAMINATION CONTROL PLAN FOR ATLAS PROGRAMS, 55-00419
- ATLAS PROGRAM PARTS, MATERIALS, AND PROCESSES REQUIREMENTS - LAUNCH VEHICLE, 11000-97-014

The above documents are configuration-controlled, released engineering specifications and are fully implemented on the Atlas program.



#### Cleanliness Requirements and Verification



- Atlas V Generic Contamination Control Plan (55-00419) Requires for Every Mission:
  - Particulate Requirement
    - DSS hardware will meet Visibly Clean Level 2 (VC-L2)
      - Inspect all exposed DSS surfaces
      - Typically produces a particle load of less than 0.1% obscuration on payload compartment surfaces.
  - Molecular Requirement
    - DSS hardware will meet Level A, NVR Requirements (1.0 mg/ft²)
      - NVR wipe sampling of DSS
      - Typical NVR levels are less than 0.5 mg/ft².



#### **Material Requirements**



- Atlas Program Parts, Materials, And Processes Requirements Launch Vehicle, 11000-97-014 Requires for *Every* Mission:
  - Non-metallics exposed to the encapsulated payload compartment:
    - TML < 1.0%, CVCM < 0.1%
    - Exceptions allowed if the predicted outgassing and deposition characteristics of the material can be accommodated in the payload contamination analysis.
    - Exceptions require approval of PMP and Contamination Control Engineering
  - Metallics exposed to the encapsulated payload compartment:
    - Cadmium, zinc, mercury and unalloyed tin are prohibited. (Note that Atlas requirement is more restrictive than SIS requirement.)
    - Exceptions allowed if rationale exists that show no adverse affects and with approval of PMP and Contamination Control Engineering.



#### **Materials Verification**



- Materials assessment summarizes inspection of payload compartment engineering drawings and verifies material selection requirements.
- Generic materials memo
  - -DSS standard materials.
  - Payload compartment materials are evaluated for metallic and non-metallic requirements.
- Mission unique memo
  - –DSS materials in the mission peculiar kit that are exposed to the payload volume are evaluated for metallic and nonmetallic requirements.



#### **Cross Contamination**



#### Particulate

- DSS compartment is isolated from upper payload by PLA diaphragm and the DSS structure, minimizing any deposition from the PLF and upper SC.
- Deposition on the upper SC from the DSS and lower SC will be minimal:
  - Per Aerophysics, there will be minimal forward flow within the PLF prior to launch and during ascent.
  - DSS compartment vents are located in aft end. The majority of particles liberated within the DSS compartment will exit through the PLF vents.

#### Molecular

- DSS compartment is isolated from upper payload by PLA diaphragm and the DSS structure, minimizing any deposition from the PLF and upper SC.
- Deposition on the upper SC from the DSS and lower SC will be small:
  - View between upper and lower SC is poor.
  - Temperature of lower SC during ascent is low, resulting in a low rate of desorption.
- Cross contamination between upper and lower SCs will be small.



### Summary



- DSS hardware will be verified to meet the standard VC L2 and NVR Level A cleanliness requirements for hardware located in the payload compartment.
- DSS materials will meet the requirements of 11000-97-014 to control molecular contamination from the DSS to the upper and lower SC.
- No cross contamination issues.

#### **Ready To Proceed to CDR**







#### Section 5.7

#### **Mass Properties**

Marilyn Maples





- Requirements
- DSS Mass Properties
  - Components
  - Vehicle mass properties at S/C separation events
- Remaining Tasks/Summary



## Requirements



- Mass Properties system level requirements as defined in Atlas V System Specification, 11000-98-022, and Atlas V Space Vehicle Interface Requirements (SVIR), 11000-98-023 are verified by Loads and Dynamics, Flight Controls and Flight Design analyses
- Derived requirements will be added to DRD 58-00808 'Adapter Systems DRD for Atlas CIII Upper Stage on Commercial Atlas AIIIB & Atlas V Launch Vehicles'



## **DSS Derived Requirements**



#### DRD 58-00808

- 3.2.4.3.9.2 Mass Properties, S/C
- Mass properties of the payloads shall be constrained to not exceed the structural capability of the Centaur and DSS, as the DSS structure is derived from the existing/flight qualified Centaur Forward Adapter (CFA).
- 3.2.4.3.9.2.1 Upper S/C
- Upper S/C shall not exceed [10,000 lbs] with mass vs. CG of TBD
- 3.2.4.3.9.2.2 Lower S/C
- Lower S/C shall not exceed [5,000 lbs] with mass vs. CG of TBD
  - Verification: Weigh S/C and analysis





- 3.2.4.3.9.3.1 DSS Weight
- DSS weight should be minimized consistent with design philosophy of using existing hardware.
- 3.2.4.3.9.3.2 Mass Properties, DSS CG Offset
  The DSS Upper Canister CG offset shall be no more than [1.0 inch].
  - Verification: Analysis



#### **DSS Mass Properties**



- Mass Properties are derived from Pro-e models for new components, modify existing relational database models and by parametric estimating
- Support provided to payload separation study.
- R&D not included, avionics, conic adapter, and ECS ducting details not finalized
- Centaur vehicle mass properties are based on "Article 99" and residuals are estimated
- Both payload separation events were analyzed for the zero plug and four plug configurations with dispersed vehicle and estimated spacecraft mass properties.
- Upper PLA included the separation system hardware. Not part of DSS baseline configuration.



## **Mass Properties – DSS Components**



58-70000-XX DSS, Zero Plug top drawing	1009.11	
58-70000-X Lower Canister including Conic adapter and C13 adapter	574.53	
58-70003-TBD Canister, DSS (modified SA and EM)	346.15	
55-74819-4 Plate - Stringer Tie, Centaur Equipment Module	3.42	
58-77670-502 RTV Silicone Sealant	4.00	
58-77670-501 Miscellaneous Hardware - Centaur Forward Adapter	6.93	
58-70003-STRUC Structural Assembly - Centaur Equipment Module	153.66	
58-70003-STUB Structure Assy Stub Adapter	178.13	
58-78651-TBD PLA Structural Assembly, C13 w/ 0.20 wall	88.38	
58-70010-CONIC Adapter ESTIMATE	100.00	
58-70000-Harnessing, Instrumentation ESTIMATE	40.00	
58-70003-TBD Upper Canister, DSS (modified SA and EM)	346.15	
55-74819-4 Plate - Stringer Tie, Centaur Equipment Module	3.42	
58-77670-502 RTV Silicone Sealant	4.00	
58-77670-501 Miscellaneous Hardware - Centaur Forward Adapter	6.93	
58-70003-STRUC Structural Assembly - Centaur Equipment Module	153.66	
58-70003-STUB Structure Assy Stub Adapter	178.13	
58-78620-DSS FWD PLA Instl - DSS Primary	88.43	
58-78620-1HDWE Hardware - Fwd Flange, B1194VS PSR	2.00	
58-78690-2 Clampband Instl, LSPSS 1194	21.80	
58-78670-1 Spring Instl	3.33	
58-78650-DSS PSR Structural Assembly	61.30	
58-70003-STUB Structure Assy Stub Adapter	173.86	

• Fwd PLA included for separation study, not part of DSS baseline



## DSS Mass Properties

608.44

0.40



1.7

ZERO Plug										
Centaur Coordinates	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
AFT canister, lwr conic adapter,										
C13 adapter	574.50	0.25	0.03	34.02	178	178	249	0.5	-0.8	0.0
Fwd canister + 1194VS + PSR	434.58	0.23	0.07	-35.18	151	151	225	-0.7	1.0	-0.3
Total DSS Zero plug	1009.08	0.24	0.05	4.22	584	584	474	-0.2	0.3	-0.4
DSS Plug (local coordinates)	173.86	0.83	0.05	-12.575	70.7	70.5	136.7	-1.1	0	0

**DSS Plug (local coordinates)** Each plug is 25.15 inches in height

Separated DSS Top Canister - ONE

ONE Plug **Centaur Coordinates** Slug-Ft\*\*2 | Slug-Ft\*\*2 | Slug-Ft\*\*2 | Slug-Ft\*\*2 | Slug-Ft\*\*2 | Slug-Ft\*\*2 Lbs Inches Inches Inches Weight ΙXο IXYo IXZo IYZo Xcg Ycg Zcg ΙYο ΙZο AFT canister, lwr conic adapter, 178 178 C13 adapter 574.50 0.25 0.03 34.02 249 0.5 -0.8 0.0 173.86 **DSS Plug** 0.83 0.05 -18.675 70.7 70.5 136.7 -1.1 Fwd canister + 1194VS + PSR 434.58 -0.7 -0.3 0.23 0.07 -60.33 151 151 225 1.0 Total DSS ONE plug 1182.94 0.33 0.05 -8.39 879 879 611 -1.3 0.1 -0.5

-48.43

268

268

362

-1.8

0.06

TWO Plug										
Centaur Coordinates	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
AFT canister, lwr conic adapter,										
C13 adapter	574.50	0.25	0.03	34.02	178	178	249	0.5	-0.8	0.0
DSS Plug	173.86	0.83	0.05	-18.675	70.7	70.5	136.7	-1.1	0	0
DSS Plug	173.86	0.83	0.05	-43.825	70.7	70.5	136.7	-1.1	0	0
Fwd canister + 1194VS + PSR	434.58	0.23	0.07	-85.48	151	151	225	-0.7	1.0	-0.3
Total DSS TWO plug	1356.80	0.39	0.05	-20.98	1255	1255	748	-2.4	-0.1	-0.6
Separated DSS Top Canister - TWO										
Plug	782.30	0.50	0.06	-61.38	427	426	499	-2.9	2.4	-0.3

Plug

-0.3



# DSS Mass Properties



THREE Plug										
Centaur Coordinates	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
AFT canister, lwr conic adapter,										
C13 adapter	574.50	0.25	0.03	34.02	178	178	249	0.5	-0.8	0.0
DSS Plug	173.86	0.83	0.05	-18.675	70.7	70.5	136.7	-1.1	0	0
DSS Plug	173.86	0.83	0.05	-43.825	70.7	70.5	136.7	-1.1	0	0
DSS Plug	173.86	0.83	0.05	-68.975	70.7	70.5	136.7	-1.1	0	0
Fwd canister + 1194VS + PSR	434.58	0.23	0.07	-110.63	151	151	225	-0.7	1.0	-0.3
Total DSS THREE plug	1530.66	0.44	0.05	-33.57	1723	1723	884	-3.5	-0.3	-0.6
Separated DSS Top Canister -										
THREE Plug	956.16	0.56	0.06	-74.19	639	638	635	-4.0	3.1	-0.4

FOUR Plug										
Centaur Coordinates	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
AFT canister, lwr conic adapter,										
C13 adapter	574.50	0.25	0.03	34.02	178	178	249	0.5	-0.8	0.0
DSS Plug	173.86	0.83	0.05	-18.675	70.7	70.5	136.7	-1.1	0	0
DSS Plug	173.86	0.83	0.05	-43.825	70.7	70.5	136.7	-1.1	0	0
DSS Plug	173.86	0.83	0.05	-68.975	70.7	70.5	136.7	-1.1	0	0
DSS Plug	173.86	0.83	0.05	-94.125	70.7	70.5	136.7	-1.1	0	0
Fwd canister + 1194VS + PSR	434.58	0.23	0.07	-135.78	151	151	225	-0.7	1.0	-0.3
Total DSS FOUR plug	1704.52	0.48	0.05	-46.16	2296	2295	1021	-4.6	-0.5	-0.7
Separated DSS Top Canister -										
FOUR Plug	1130.02	0.60	0.06	-86.93	916	915	772	-5.1	3.7	-0.4



#### **Vehicle Mass Properties at Lwr S/C Separation**



- After Upper Payload separation and upper canister separation
- S/C range 1,000-5,000 lbs., CG @ center of DSS canister w/ zero plugs

	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
Centaur (Dry) 4X1	4831.30	3.90	-0.60	282.40	30775	30960	2413	20	236	-516
DSS aft canister, conic, C13	574.50	0.25	0.03	34.02	178	178	249	1	-1	0
Residuals at SV Sep *	527.22	-3.67	-0.46	394.79	876	903	41	1	-36	-4
Centaur w/ Lwr Canister, Conic										
and C13, Constrained residuals	5933.02		-0.53	268.34		40882	2710		197	-536
Payload**	1,000.00	0.00	0.00	-6.10	200				0	0
Centaur @ SV Sep	6933.02	2.46	-0.45	228.75	54774	54995	2812	21	342	-563
Payload**	2,000.00	0.00	0.00	-6.10	400	400	200	0	0	
Centaur @ SV Sep	7933.02	2.15	-0.39	199.15	65378	65600	2913	21	451	-583
Payload**	3,000.00	0.00	0.00	-6.10	600	600	300	0	0	0
Centaur @ SV Sep	8933.02	1.91	-0.35	176.17	73653	73876	3014	21	536	-599
Payload**	4,000.00	0.00	0.00	-6.10	800	800	400	0	0	0
Centaur @ SV Sep	9933.02	1.72	-0.31	157.82		80525			603	-611
Payload**	5,000.00	0.00	0.00	-6.10	1000	1000	500	0	0	0
Centaur @ SV Sep	10933.02	1.56	<b>-0.29</b>	142.83		<b>85995</b>			659	

<sup>\*</sup> Propellant trapped in lines, gas, helium, hydrazine, ice

<sup>\*\*</sup> Payload CG at Center of DSS canister w/ No plugs is -6.1 Centaur Z



#### **Vehicle Mass Properties at Lwr S/C Separation**



- After Upper Payload separation and upper canister separation
- S/C range 1,000-5,000 lbs., CG @ center of DSS canister w/ four plugs

	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
Centaur w/ Lwr Canister, Conic										
and C13, Constrained residuals	5933.02	2.87	-0.53	268.34	40663	40882	2710	21	197	-536
Payload**	1,000.00	0.00	0.00	-56.40	200	200	100	0	0	0
Centaur @ SV Sep	6933.02	2.46	-0.45	221.50	60341	60562	2812	21	369	-568
Payload**	2,000.00	0.00	0.00	-56.40	400	400	200	0	0	0
Centaur @ SV Sep	7933.02	2.15	-0.39	186.47	75109	75330	2913	21	498	-592
	-	-	-			<del>-</del>	•			
Payload**	3,000.00	0.00	0.00	-56.40	600	600	300	0	0	0
Centaur @ SV Sep	8933.02	1.91	-0.35	159.28	86615	86837	3014	21	598	-610
	-	-	-			<del>-</del>	•			
Payload**	4,000.00	0.00	0.00	-56.40	800	800	400	0	0	0
Centaur @ SV Sep	9933.02	1.72	-0.31	137.57	95844	96067	3114	21	678	-625
Payload**	5,000.00	0.00	0.00	-56.40	1000	1000	500	0	0	0
Centaur @ SV Sep	10933.02	1.56	-0.29	119.82	103422	103646	3215	21	743	-637

<sup>\*</sup> Propellant trapped in lines, gas, helium, hydrazine, ice

<sup>\*\*</sup> Payload CG at Center of DSS canister w/ 4 plugs is at -56.4 Centaur Z



#### **Vehicle Mass Properties after Upr S/C Separation**



- After Upper Payload separation before upper canister separation
- S/C range 1,000-5,000 lbs., CG @ center of DSS canister w/ zero plugs

	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
Centaur (Dry) 4X1	4831.30	3.90	-0.60	282.40	30775	30960	2413	20	236	-516
Zero Plug DSS + Fwd adapter	1,009.08	0.24	0.05	4.22	584.13	584.13	474.20	-0.20	0.27	-0.45
Residuals at SV Sep *	527.22	-3.67	-0.46	394.79	876	903	41	1	-36	-4
Centaur w/ Zero plug DSS, Conic										
and C13, Fwd adapter,										
constrained residuals	6367.60	2.69	-0.49	247.62	48865	49085	2936	21	268	-553
Payload**	1,000.00	0.00	0.00	-6.10	200	200	100	0	0	0
Centaur @ SV Sep	7367.60	2.33	-0.42	213.18	61074	61295	3037	20	395	-576
Payload**	2,000.00	0.00	0.00	-6.10	400	400	200	0	0	
Centaur @ SV Sep	8367.60	2.05	-0.37	186.98	70412	70634	3138	20	492	-593
Payload**	3,000.00	0.00	0.00	-6.10	600	600	300	0	,	
Centaur @ SV Sep	9367.60	1.83	-0.33	166.37	77800	78022	3239	20	569	-607
Payload**	4,000.00		0.00	-6.10		800		0		
Centaur @ SV Sep	10367.60	1.65	-0.30	149.73	83801	84024	3340	20	630	-618
Payload**	5,000.00		0.00	-6.10	1000	1000	500	0		
Centaur @ SV Sep	11367.60	1.51	-0.27	136.02	88781	89005	3440	20	681	-627

<sup>\*</sup> Propellant trapped in lines, gas, helium, hydrazine, ice

<sup>\*\*</sup> Payload CG at Center of DSS canister w/ No plugs is -6.1 Centaur Z



#### **Vehicle Mass Properties after Upr S/C separation**



- After Upper Payload separation before upper canister separation
- S/C range 1,000-10,000 lbs., CG @ center of DSS canister w/ four plugs

	Lbs	Inches	Inches	Inches	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2	Slug-Ft**2
	Weight	Xcg	Ycg	Zcg	IXo	IYo	IZo	IXYo	IXZo	IYZo
Centaur (Dry) 4X1	4831.30	3.90	-0.60	282.40	30775	30960	2413	20	236	-516
Four Plug DSS + Fwd adapter	1,704.52	0.48	0.05	-46.16	2,296.17	2,295.40	1,021.03	-4.60	-0.52	-0.67
Residuals at SV Sep *	527.22	-3.67	-0.46	394.79	876	903	41	1	-36	-4
Centaur w/ Zero plug DSS, Conic										
and C13, Fwd adapter,										
constrained residuals	7063.04	2.51	-0.43	211.50	67438	67657	3483	16	366	-579
Payload**	1,000.00	0.00	0.00	-56.40	200	200	100	0	0	0
Centaur @ SV Sep	8063.04	2.20	-0.38	178.27	81207	81427	3584	16	493	-601
Payload**	2,000.00	0.00	0.00	-56.40	400	400	200	0	0	0
Centaur @ SV Sep	9063.04	1.96	-0.34	152.38	91982	92203	3685	16	592	-618
Payload**	3,000.00	0.00	0.00	-56.40	600	600	300	0	0	0
Centaur @ SV Sep	10063.04	1.76	-0.30	131.63	100655	100877	3786	16	672	-632
Payload**	4,000.00	0.00	0.00	-56.40	800	800	400	0	0	
Centaur @ SV Sep	11063.04	1.60	-0.28	114.64	107797	108019	3887	16	737	-643
Payload**	5,000.00	0.00	0.00	-56.40	1000	1000	500		0	
Centaur @ SV Sep	12063.04	1.47	-0.25	100.46	113787	114010	3987	15	791	-653
Payload**	10,000.00	0.00	0.00	-131.10	2000	2000	1000		0	•
Centaur @ SV Sep	17063.04	1.04	-0.18	10.71	174304	174529	4489	15	1134	-712

<sup>\*</sup> Propellant trapped in lines, gas, helium, hydrazine, ice

<sup>\*\*</sup> Payload CG at Center of DSS canister w/ 4 plugs is at -56.4 Centaur Z





Remaining Tasks

Update mass properties for instrumentation, harnessing, conic adapter, and ECS ducting as designs mature.

Summary

### **Ready To Proceed to CDR**







### Section 5.8

### **Control Dynamics**

Bob Utrup Keith Pearen





- DSS and Atlas V System Requirements
  - Separation
  - Stability
- Separation Analysis Methodology
- Separation Input Assumptions
- Separation Results
- Stability Results
- Compliance
- Risk Items
- Remaining Tasks
- Summary



### Requirements



System Specification Requirements-(11000-98-022)

- 3.1.1.2.5 Perform Separation
  - Separation analyses will be performed prior to CDR
    - Upper SV separation
    - DSS upper / lower canister separation
    - Lower SV separation
  - Analyses will be designed to cover worst-case credible separation conditions
    - Worst-case mass properties
    - Spin vs. no spin
    - Standard dispersions and tolerances
- 3.2.3.1 Stable Flight
  - Perform stability margin assessment to verify stability margin requirements
    - Nominal and dispersed



### **Requirements - Continued**



Space Vehicle Interface Requirements (SVIR) (11000-98-023)

- 3.1.4.3 Separation Requirements
  - 3.1.4.3.1 Separation Mechanism
    - The separation mechanism will be provided by the SV
  - 3.1.4.3.2 Separation Velocity
    - The Atlas V System residual thrust after payload separation shall ensure no recontact with the SV assuming the SV provided separation system will provide no less than 1 ft/sec relative separation velocity
  - 3.1.4.3.3 Separation Inhibits
    - As required by specific mission(s), the Atlas V System shall be capable of enabling/inhibiting
      the Reaction Control System (RCS) up to one (1) second before and up to five (5) seconds
      after payload separation.
  - 3.1.4.3.4 Separation Contingencies
    - The Atlas V System will have the flexibility to incorporate mission unique nominal and contingency flight sequences.

#### DSS Derived Requirements (58-00808 DRD)

- 3.2.4.3.9.5 DSS Separation Requirements
  - 3.2.4.3.9.5.4
    - Once the separation bolts function, [4] springs (PN 55-78632-4) will 'thrust' the upper canister away from lower canister so that no contact occurs with the lower S/C or lower canister
  - 3.2.4.3.9.5.4.1
    - As a contingency for failure of the upper S/C to separate from the DSS, the DSS should, as a goal, be designed so that the upper canister will provide adequate clearance, from the lower S/C, with the upper S/C still attached.
- All requirements will be verified through analysis



### Separation Analysis Methodology



- The general methodology used for these analyses is based on the following elements:
  - Fixed components
    - Wet Centaur mass properties
    - Lower DSS section
    - Conic Adapter
    - Unusable Centaur propellants
    - C13 Adapter
    - 4 separation springs
    - 2 61-pin electrical disconnects for lower and upper payload separation
      - Analysis assumes the disconnects are split 180 deg. apart
    - 8 total electrical disconnects for DSS canister separation
      - Analysis assumes 4 disconnects each at 2 locations 180 deg. apart
  - Variable components
    - Payload mass properties
    - Separation type (3-axis stabilized, 30 deg/sec, etc...)
    - Centaur propellant excess (PE)



### **Separation Analysis Methodology**



- The separation types and payload mass property ranges are selected to reflect the bounds defined in the SVIR for the Atlas V 4m configuration
  - Separation Types
    - 3-Axis Stable
    - 0.6 deg/sec, typical low rate spinner
    - 2.5 deg/sec, typical low rate spinner
    - 30 deg/sec, typical high rate spinner
  - Lower payload mass property range
    - 500-6500 lbm
  - Upper payload mass property range
    - 500-10,500 lbm
  - 0 plug & 4 plug configurations



# Input Assumptions Centaur Mass Properties



Centaur mass properties in Centaur Structural coordinates

_	Total Mass	5933.02 ± 110 lbm
	<ul> <li>Wet Centaur</li> </ul>	4831.30 lbm
	<ul> <li>Residuals</li> </ul>	527.22 lbm
	<ul> <li>DSS aft canister and C13</li> </ul>	574.50 lbm

CG Locations

<ul> <li>Axial CGz</li> </ul>	268.34 ± 2.5 inches
<ul> <li>Lateral CGx</li> </ul>	$2.46 \pm 0.5$ inches
<ul> <li>Lateral CGy</li> </ul>	$-0.45 \pm 0.5$ inches

Moments of Inertia

•	lxx	$40663 \pm 500 \text{ slug-ft2}$
•	lyy	40882 ± 500 slug-ft2
•	Izz	2710 ± 90 slug-ft2

Products of Inertia

•	lxy	$21 \pm 20 \text{ slug-ft2}$
•	lxz	197 ± 100 slug-ft2
•	lyz	$-536 \pm 100 \text{ slug-ft2}$



# Input Assumptions <a href="Lower Payload Mass Properties">Lower Payload Mass Properties</a>



Nominal Properties (X axis = payload Longitudinal axis)

	Mass Ibm	CG <sub>x</sub> inches	CG <sub>y</sub> inches	CG <sub>z</sub> inches	I <sub>xx</sub> slug-ft²	l <sub>yy</sub> slug-ft²	l <sub>zz</sub> slug-ft²	I <sub>xy</sub> slug-ft²	l <sub>xz</sub> slug-ft²	l <sub>yz</sub> slug-ft²
1K	1000	50	0	0	382.30	805.75	805.75	0	0	0
2K	2000	55	0	0	692.50	1426.25	1426.25	0	0	0
3K	3000	60	0	0	1002.83	2046.75	2046.75	0	0	0
4K	4000	65	0	0	1313.16	2667.25	2667.25	0	0	0
5K	5000	70	0	0	1623.50	3287.75	3287.75	0	0	0
6K	6000	75	0	0	1933.83	3908.25	3908.25	0	0	0

#### **Uniform Dispersions**

	Mass Ibm	CG <sub>x</sub> inches	CG <sub>y</sub> inches	CG <sub>z</sub> inches	l <sub>xx</sub> slug-ft²	l <sub>yy</sub> slug-ft²	l <sub>zz</sub> slug-ft²	l <sub>xy</sub> slug-ft²	l <sub>xz</sub> slug-ft²	l <sub>yz</sub> slug-ft²
1K	500	15	5	5	298.98	680.75	680.75	50.00	50.00	50.00
2K	500	15	5	5	442.50	1051.25	1051.25	87.50	87.50	87.50
3K	500	15	5	5	586.16	1421.75	1421.75	125.00	125.00	125.00
4K	500	15	5	5	729.83	1792.25	1792.25	162.50	162.50	162.50
5K	500	15	5	5	873.50	2162.75	2162.75	200.00	200.00	200.00
6K	500	15	5	5	1017.17	2533.25	2533.25	237.50	237.50	237.50



# Input Assumptions <u>Upper Payload Mass Properties</u>



**Nominal Properties** (X axis = payload Longitudinal axis)

	Mass Ibm	CG <sub>x</sub> inches	CG <sub>y</sub> inches	CG <sub>z</sub> inches	I <sub>xx</sub> slug-ft²	l <sub>yy</sub> slug-ft²	l <sub>zz</sub> slug-ft²	l <sub>xy</sub> slug-ft²	l <sub>xz</sub> slug-ft²	l <sub>yz</sub> slug-ft²
1K	1000	50	0	0	382.30	805.75	805.75	0	0	0
2K	2000	55	0	0	692.50	1426.25	1426.25	0	0	0
3K	4000	65	0	0	1313.16	2667.25	2667.25	0	0	0
4K	6000	75	0	0	1933.83	3908.25	3908.25	0	0	0
5K	8000	85	0	0	2554.50	5149.25	5149.25	0	0	0
6K	10,000	95	0	0	3175.17	6390.25	6390.25	0	0	0

#### **Uniform Dispersions**

	Mass Ibm	CG <sub>x</sub> inches	CG <sub>y</sub> inches	CG <sub>z</sub> inches	l <sub>xx</sub> slug-ft²	l <sub>yy</sub> slug-ft²	l <sub>zz</sub> slug-ft²	I <sub>xy</sub> slug-ft²	l <sub>xz</sub> slug-ft²	l <sub>yz</sub> slug-ft²
1K	500	15	5	5	298.98	680.75	680.75	50.00	50.00	50.00
2K	500	15	5	5	442.50	1051.25	1051.25	87.50	87.50	87.50
3K	500	15	5	5	729.83	1792.25	1792.25	162.50	162.50	162.50
4K	500	15	5	5	1017.17	2533.25	2533.25	237.50	237.50	237.50
5K	500	15	5	5	1304.50	3274.25	3274.25	312.50	312.50	312.50
6K	500	15	5	5	1591.83	4015.25	4015.25	387.50	387.50	387.50

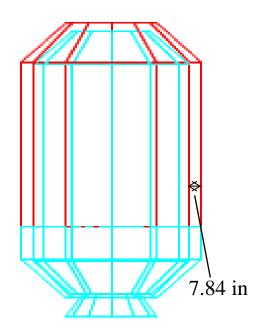


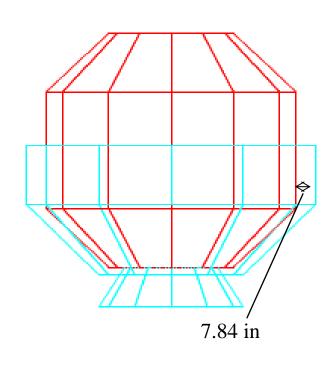
### **Clearance Geometries**

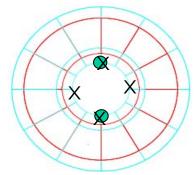


### Aft view Lower payload

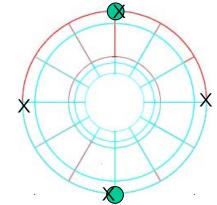
DSS canister separation (4 plug)\* Lower payload separation\*







Aft view DSS canister



\*Payload geometries defined in SRR

- X Spring locations
- Electrical disconnect locations

DSS PDR 30 Sept. 2008



### **Upper Payload Separation Results**



- Varied upper spacecraft mass properties
- Runs completed with both 2,000 and 4,000 lbm lower spacecraft mass properties
- Worst case Tip-off rates at Separation Command (absolute values)\*

4 Plug only

+ Flug Offiy	3-Axis	Stable	0.6 de	g/sec	2.5 de	eg/sec	30 deg/sec	
	Pitch (deg/sec)	Yaw (deg/sec)	Pitch (deg/sec)	Yaw (deg/sec)	Pitch (deg/sec)	Yaw (deg/sec)	Pitch (deg/sec)	Yaw (deg/sec)
Mission Planners Guide Requirements	±0.2	±0.2	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6
1K	0.031	0.029	0.029	0.027	0.035	0.027	0.159	0.176
2K	0.029	0.028	0.031	0.026	0.031	0.026	0.162	0.172
3K	0.029	0.027	0.031	0.024	0.028	0.030	0.155	0.152
4K	0.029	0.025	0.031	0.024	0.029	0.031	0.158	0.154
5k	0.029	0.024	0.027	0.027	0.029	0.039	0.145	0.149
6k	0.028	0.022	0.028	0.022	0.030	0.036	0.149	0.159

<sup>\*</sup> Values shown are worst case out of 1000 case monte carlo



## **DSS Canister Separation Results**



- Nominal static clearance used 7.84 inches
- Varied lower spacecraft mass properties
- 1.0 inch lateral CG dispersion on separating portion of DSS canister
  - 3.2.4.3.9.3.2 requires the CG offset of the separating canister shall be no more than [1.0 inch]
- 3 axis stable

		0 Plug		4 plug				
	Worst Case Clearance (in)*	Clearance Loss (in)	Clearance Loss (%)	Worst Case Clearance (in)*	Clearance Loss (in)	Clearance Loss (%)		
1K	6.86	0.98	12.5	-0.76	8.60	109.7		
2K	6.85	0.99	12.6	-1.07	8.91	113.6		
ЗК	6.86	0.98	12.5	-0.72	8.56	109.2		
4K	6.86	0.98	12.5	-0.74	8.58	109.4		
5k	6.86	0.98	12.5	-0.61	8.45	107.8		
6k	6.87	0.97	12.4	-0.74	8.58	109.4		

<sup>\*</sup> Values shown are worst case out of 1000 case monte carlo



## **DSS Canister Separation Results**



- Nominal static clearance used 7.84 inches
- Varied lower spacecraft mass properties
- 0.5 inch lateral CG dispersion on separating portion of DSS canister
- 3 axis stable

		0 Plug		4 plug				
	Worst Case Clearance (in)*	Clearance Loss (in)	Clearance Loss (%)	Worst Case Clearance (in)*	Clearance Loss (in)	Clearance Loss (%)		
1K	7.01	0.83	10.6	0.05	7.79	99.4		
2K	7.01		10.6	0.30	7.54	96.2		
3К			10.6	0.33	7.51	95.8		
4K	7.02	0.82	10.5	0.34	7.50	95.7		
5k	7.02	0.82	10.5	0.15	7.69	98.1		
6k	7.01	0.83	10.6	0.22	7.62	97.2		

<sup>\*</sup> Values shown are worst case out of 1000 case monte carlo



## **Lower Payload Separation Results**



- Nominal static clearance used 7.84 inches
- Varied lower spacecraft mass properties

	3-Axis Stable			0.6 deg/sec			2.5 deg/sec			30.0 deg/sec*		
	Worst Case Clear. (in)**	Clear. Loss (in)	Clear. Loss (%)									
1K	3.58	4.26	54.3	3.58	4.26	54.3	3.57	4.27	54.5	5.60	2.24	28.6
2K	3.82	4.02	51.3	3.80	4.04	51.5	3.79	4.05	51.7	3.72	4.12	52.6
3K	3.71	4.13	52.7	3.70	4.14	52.8	3.69	4.15	52.9	2.58	5.26	67.1
4K	3.55	4.29	54.7	3.54	4.30	54.8	3.53	4.31	55.0	1.55	6.29	80.2
5k	3.37	4.47	57.0	3.36	4.48	57.1	3.36	4.48	57.1	0.56	7.28	92.9
6k	3.21	4.63	59.1	3.20	4.64	59.2	3.20	4.64	59.2	-2.12	9.96	127.0

<sup>\* 30.0</sup> deg/sec runs conducted with 0.5 inch lateral dispersion

<sup>\*\*</sup> Values shown are worst case out of 1000 case monte carlo



## Failed Upper Payload Separation Results



- Separation of DSS canister while the failed upper payload is still attached
- Numbers are not bounding but show recontact concerns
  - Parametric analysis not performed
- 0 plug case ran with 10,000 lbm upper payload attached
- 4 plug case ran with 6,000 lbm upper payload attached
- 3 axis stable 5 inch lateral CG dispersion on entire separating body

	DSS Canister Sep.				
	Worst Case Clearance (in)*	Clearance Loss (in)	Clearance Loss (%)		
0 Plug	-2.32	10.16	129.6		
4 Plug	-7.74	15.58	198.7		

<sup>\*</sup> Values shown are worst case out of 1000 case monte carlo



### **Failed Upper Payload Separation Results**



- Separation of DSS canister while the failed upper payload is still attached
- Numbers are not bounding but show recontact concerns
  - Parametric analysis not performed
- 0 plug case ran with 10,000 lbm upper payload attached
- 4 plug case ran with 6,000 lbm upper payload attached
- 3 axis stable 2 inch lateral CG dispersion on entire separating body

	DSS Canister Sep.				
	Worst Case Clearance (in)*	Clearance Loss (in)	Clearance Loss (%)		
0 Plug	2.68	5.16	65.8		
4 Plug	-1.13	8.97	114.4		

It should be noted that a failure to separate is highly unlikely to occur.

It is likely that the majority of potential payloads will have mass properties and dimensions that are conducive to separating without recontact under this failed case.

<sup>\*</sup> Values shown are worst case out of 1000 case monte carlo



### **Separation Summary**



- Upper Payload
  - Assessment using bounding payload mass properties gives reasonable results
    - Mission Unique Requirements will be handled on a mission by mission basis
- DSS Canister
  - 0 Plug
    - 0.5 inch lateral CG offset dispersion
      - Worst case lateral clearance loss 0.83 inches 10.6%
    - 1.0 inch lateral CG offset dispersion
      - Worst case lateral clearance loss 0.99 inches 12.6%
  - 4 Plug
    - 0.5 inch lateral CG offset dispersion
      - Worst case lateral clearance loss 7.79 inches 99.4%
    - 1.0 inch lateral CG offset dispersion
      - Worst case lateral clearance loss 8.91 inches 113.6%



### **Separation Summary - Continued**



- DSS Canister
  - Upper Payload Failure Contingency
    - 0 Plug 2 inch lateral CG dispersion
      - Lateral clearance loss ~ 5.16 inches 65.8%
    - 4 Plug 2 inch lateral CG dispersion
      - Lateral clearance loss ~ 8.97 inches 114.4%
    - 0 Plug 5 inch lateral CG dispersion
      - Lateral clearance loss ~ 10.16 inches 129.6%
    - 4 Plug 5 inch lateral CG dispersion
      - Lateral clearance loss ~ 15.58 inches 198.7%
- Lower Payload
  - 3 Axis Stable
    - Worst case lateral clearance loss 4.63 inches 59.1%
  - 0.6 deg/sec spinner
    - Worst case lateral clearance loss 4.64 inches 59.2%
  - 2.5 deg/sec spinner
    - Worst case lateral clearance loss 4.64 inches 59.2%
  - 30 deg/sec spinner
    - Worst case lateral clearance loss 9.96 inches 127.0%
- Low Risk
  - Revising preliminary envelopes would allow all cases to clear without contacting





# Stability Assessment Keith Pearen



### **Stability Assessment**



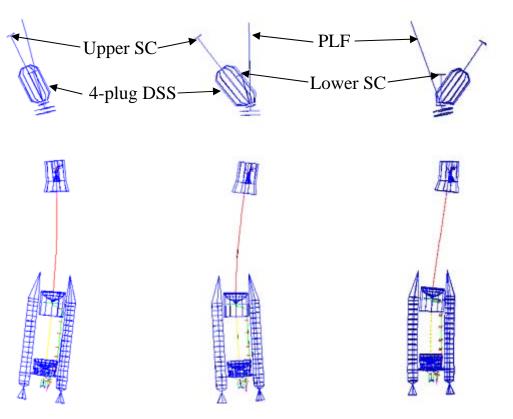
- Dynamic properties of DSS could significantly decrease boost phase stability margins.
- Autopilot stability margins were assessed for four configurations
  - 401 with 0-plug DSS
    - Upper payload is a 10,000 lb indicator payload.
    - Lower payload is a 5,000 lb indicator payload.
    - Boost phase autopilot design meets requirements.
  - 431 with 0-plug DSS
    - Upper payload is a 10,000 lb indicator payload.
    - Lower payload is a 5,000 lb indicator payload.
    - Single time-point autopilot design (Max Q) meets requirements.
  - 401 with 4-plug DSS
    - Upper payload is a 5,500 lb 'real' payload.
    - Lower payload is a 6,000 lb 'real' payload.
    - Single time-point autopilot design (Max Q) meets requirements.
  - 431 with 4-plug DSS
    - Upper payload is a 5,500 lb 'real' payload.
    - Lower payload is a 6,000 lb 'real' payload.
    - Single time-point autopilot design (Max Q) meets requirements.



### **Stability Assessment**



- Structural Yaw Modes\* of Atlas V 431 with 4 plug DSS at Maximum Dynamic Pressure



Increased second mode energy complicates autopilot design. An out of phase second mode is common in single payload missions, but the DSS design increases this "scissor mode" effect.

Indicator payloads as used with the 0-plug configuration have a similar effect on the first mode, which creates an unrealistic design challenge. Despite this additional complexity the 0-plug configurations meet margin requirements

First Bending Mode

Second Bending Mode - In Phase

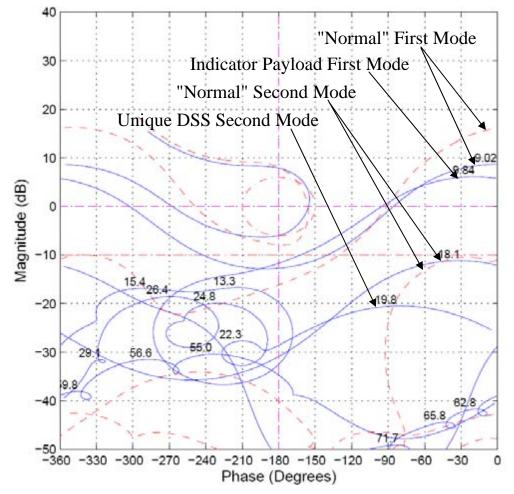
Second Bending
Mode - Out of Phase

<sup>\*</sup> Not to Scale.





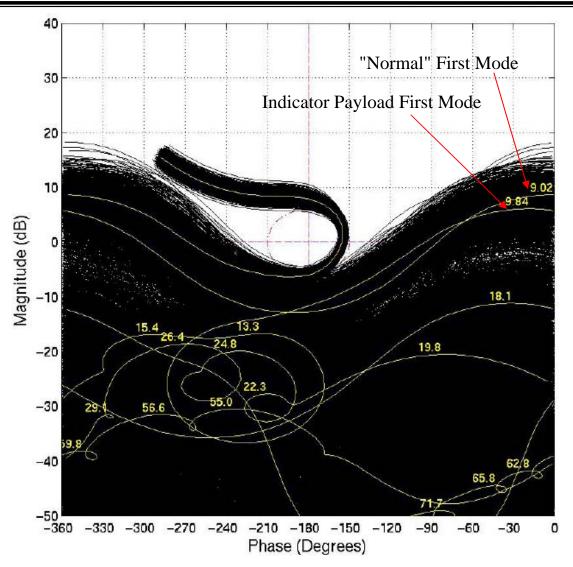
- Nichol's plot for 401 with 0-plug DSS
  - Pitch plane at T = 88.0 sec
    - Max Q
  - Solid blue is DSS
  - Dashed red is a representative 401 with single payload
  - All nominal stability margin requirements are satisfied.







- Dispersed Nichol's plot for 401 with 0-plug DSS
  - Pitch plane at T = 88.0 sec
    - Max Q
  - 1000 run Monte Carlo analysis
  - All dispersed margin requirements satisfied







### DSS 0-plug 401 Boost Phase Nominal Stability Margins

Nominal Linear Stability Margin		Acceptance	DSS 401 0-plug	AV-015
Law Francisco Cain (dD)	Roll	≥ 6	18.4	18.0
Low Frequency Gain (dB)	Pitch/Yaw	≥ 4	6.1	7.9
Rigid Body Phase (deg)	Roll	≥ 20	30.4	30.2
	Pitch/Yaw	≥ 15	26.4	20.5
Rigid Body Gain (db)	Roll	≥ 4	9.8	8.1
	Pitch/Yaw	≥ 4	5.8	6.7
First Mode Frontside Phase (deg)		≥ 30	61.8	62.9
First Mode Backside Phase (deg)		≥ 45	86.9	93.5
Second Mode Closest Approach (dBU)		3σ Stable	16.1	27.1
Third & Higher Modes Attenuation (dB	3)	3σ Stable	31.1	31.5

<sup>\*</sup> Closest Approach Margin provided in dBU (dB Units) dB Units = sqrt((phase(deg)\*(6dB/30deg))^2+(gain(dB))^2)





### DSS 0-plug 401 Boost Phase Minimum Dispersed Stability Margins

Linear Stability Margin	Plane	Acceptance	DSS 401 0-plug		AV-015	
			Nom	$3\sigma$	Nom	$3\sigma$
Aero Gain (dB)	Pitch	≥ 3 dB	6.5	4.5	8.0	6.3
	Yaw	≥ 3 dB	6.1	4.6	8.4	6.5
Rigid Body Phase (deg)	Pitch	≥ 10 deg	26.4	23.9	20.5	16.7
	Yaw	≥ 10 deg	26.5	23.7	21.7	18.4
Rigid Body Gain (dB)	Pitch	≥ 2 dB	5.8	3.7	6.7	5.4
	Yaw	≥ 2 dB	5.9	4.2	6.7	5.4
1 <sup>st</sup> Mode Phase (deg)	Pitch	≥ 25 deg	71.9	43.8	68.5	49.1
	Yaw	≥ 25 deg	68.4	35.9	67.3	46.9
2 <sup>nd</sup> and Higher Mode Closest Approach (dBU)	Pitch	3σ Stable	16.1	9.3	32.4	8.0
	Yaw	3σ Stable	18.0	7.2	28.2	6.1





- Single Time Point Boost Phase Nominal Stability Margins
  - Pitch plane margins at Maximum Dynamic Pressure
    - DSS 431 0-plug @ t = 58.0 sec
    - DSS 401 4-plug @ t = 96.0 sec
    - DSS 431 4-plug @ t = 52.0 sec
  - Single time point assessment indicates no obvious risk items

Nominal Linear Stability Margin	Acceptance	DSS 431 0-plug	DSS 401 4-plug	DSS 431 4-plug
		U-plug	4-plug	4-plug
Low Frequency Gain (dB):	≥ 4.0	8.1	6.4	7.2
Rigid Body Phase (deg):	≥ 15.0	24.9	25.6	24.3
Rigid Body Gain (dB):	≥ 4.0	7.2	5.6	8.8
First Mode Frontside Phase (deg)	≥ 30.0	85.2	81.6	92.2
First Mode Backside Phase (deg)	≥ 45.0	91.8	86.0	100.0
Second Mode Closest Approach (dBU)*	3σ Stable	22.8	15.3	19.5
Third & Higher Modes Attenuation (dB)	3σ Stable	29.7	32.8	27.3

<sup>\*</sup> Closest Approach Margin provided in dBU (dB Units) dB Units = sqrt((phase(deg)\*(6dB/30deg))^2+(gain(dB))^2)



## **Stability Summary**



- Autopilot design for 401 with 0-plug DSS
  - Satisfies margin requirements
  - Low Risk
- Preliminary analysis of remaining configurations
  - Satisfies margin requirements for single time point
  - No obvious risk items for remainder of boost phase
  - Low Risk



### Compliance



System Specification Requirements-(11000-98-022)

- 3.1.1.2.5 Perform Separation
  - 30 deg/sec spinner
    - There are a few cases where, using preliminary envelopes as reference, a lower payload spinning at 30 deg/sec contacts the lower DSS canister
    - Requires verification on a case by case basis
  - 4 plug canisters with lateral CG's less than 0.5 inches clear the preliminary payload envelope successfully
  - 4 plug canisters with lateral CG's between 0.5 and 1.0 inches contact the preliminary payload envelope during the separation event
- 3.2.3.1 Stable Flight
  - Perform stability margin assessment to verify stability margin requirements
    - Generic analysis indicates stability margin requirements are achievable
    - Stability margins are highly sensitive to mission unique SV dynamics

Space Vehicle Interface Requirements (SVIR) (11000-98-023)

- 3.1.4.3 Separation Requirements
  - Standard Atlas V requirements
    - No conflicting DSS requirements

#### DSS Derived Requirements (58-00808 DRD)

- 3.2.4.3.9.5 DSS Separation Requirements
  - 0 plug canisters with both 0.5 and 1.0 inch lateral CG dispersions clear the preliminary envelope successfully
  - 4 plug canisters with lateral CG's less than 0.5 inches clear the preliminary payload envelope successfully
  - 4 plug canisters with lateral CG's between 0.5 and 1.0 inches may contact the preliminary payload envelope during the separation event
  - Both 0 and 4 plug configurations show larger clearance loss when the upper SC fails to separate
    - Requires verification on a case by case basis





### CDR

- Verification of remaining requirements:
  - 3.2.3.2 Upper Stage Pre-Payload –Separation Maneuver
  - 3.2.3.3 Park Orbit or Transfer Orbit Coast
  - 3.2.3.4 Final Delivery to Orbit Maneuvers
- Verify sufficient hydrazine for performance needs
- Complete booster stability margin assessment for 4 plug configuration
- Complete Centaur stability margin assessment

### **Ready To Proceed to CDR**







### Section 5.9

### **System Safety**

Darrell J. RAY



### **Topics**



- DSS System Safety Requirements
- Compliance of DSS preliminary design with Safety requirements
- Verification of Safety requirements (by analysis, test, demo, etc.)
   and estimated completion date of verifications
- Risk
- Future Tasks
- Summary



### Requirements



Adapters DRD, 58-00808, ¶3.7:

The systems shall comply with EWR\_127-1, "Range Safety Requirements," as tailored.

- Significant 127-1 requirements (examples only, others may apply):
  - Overall: §3.3 "General Design Policy" (fault tolerance requirements)
  - Flight Hardware:
    - §3.6.2.6 "Flight Hardware Used to Lift Critical Loads" (lift fittings design requirements)
    - §3.13 "Ordnance Systems" (inhibits / harness / EMC design requirements)
  - Ground Support Equipment:
    - §3.6.2.3 "Sling Assemblies Used to Handle Critical Hardware" (design / test rqmts)
    - §3.6.2.7 ". . . Personnel Work Platforms" (design / test requirements)
  - Ground Operations:
    - §6.6 "Material Handling Equipment Operations" (per procedure)
    - Appendix 6B "Hazardous and Safety Critical Procedure Requirements" (content / format)



### **Compliance**



- Approach Design engineers implement as part of "normal" work
  - Design for Minimum Risk (DFMR)
    - Incorporate adequate factors of safety
    - Maintain positive margins
  - Fault Tolerance (FT)
    - Two FT (3, independent, inhibits) against CATASTROPHIC hazards
    - One FT (2, independent, inhibits) against CRITICAL hazards
  - Procedural Precautions (primarily for operations)
    - Nominally, in addition to, not in lieu of, DFMR & FT features
    - Clear, concise, step-by-step instructions
    - CAUTIONs and WARNINGs, where appropriate
- Documentation ultimate approval by Range Safety
  - Existing components: In Safety Assessment Report (SAR), 14000-00-020, Rev G
  - "New" and/or "New Application" components:
    - Typically addressed initially in a "first use," Mission-Unique (MU-) Missile System Prelaunch Safety Package (MSPSP)
    - Eventually, would be reflected in SAR at first, subsequent revision



### **Verifications**



- Methodology (A, T, D, I as appropriate)
  - Per "nominal" component plan
  - Using "existing" documentation

### Examples

- Flight Hardware
  - Structural Analysis
  - (Limited) Proof-testing primarily "lift fittings"
  - Electromagnetic Compatibility Analysis primarily ordnance items/circuitry/harnessing
- Ground Support Equipment
  - Structural Analysis
  - Proof-testing
  - Non-destructive Inspection (dye penetrant, radiographic, ultrasonic, or similar)
- Ground Operations Procedure Review

#### ECD

- Consistent with component development schedule
- Adjusted, as necessary, to support "first flight"



### Risk



### Flight Hardware – Low

- Mostly existing hardware used in "new" application; limited number of "new" parts
- Existing hardware qualified for current application; "new" application should not violate previous qualification
- Limited number of "new" parts; design/verification requirements understood

### Ground Support Equipment – Low

- Planned "existing" hardware usage similar/identical to prior usage
- "New" hardware similar to existing; designers familiar with requirements

### Ground Operations – Low

- "New" operations similar to previous; designers familiar with requirements
- Post (fairing) encapsulation operations essentially unchanged from existing

### "Watch" Items – all workable, but currently incompletely defined

- Lower payload contingency propellant offload: access; spacecraft compliance
- Potential for operations under suspended loads during lower payload stack-up
- Lower payload separation device: access/installation approach/timing



### **Future Tasks**



### To get to –

- CDR: As part of normal design process (Table Top's, etc.)
  - Provide detailed/specific requirements to component/system designers
  - Review analytical (& other) verification documentation, as it becomes available
- ILC: As part of normal design process (Table Top's, etc.)
  - Review testing (& other) verification documentation, as it becomes available
  - Develop descriptive & compliance summary for inclusion in an MU-MSPSP



# **Summary**



- Requirements identified and understood
  - Existing hardware complies; "new" application not expected to void compliance
  - "New" hardware also expected to comply; similar to existing hardware
  - "New" operations also similar to existing operations; compliance expected
- Verification of compliance with Safety requirements will be "in-line"
   with functional/performance verifications (goal = nothing additional)
- Compliance documentation
  - Initially, via a Mission-Unique MSPSP;
  - Eventually, to be incorporated in Launch Vehicle SAR
- Risk = Low
- Remaining tasks understood & within current experience base

### **Ready To Proceed to CDR**







### Section 6.1

### **Avionics**

Joven DeHerrera





- General
  - East Coast only
  - Atlas V 4xy Vehicle Configurations
    - Baseline vehicle configuration
  - Each SC shall have 3 independent hardware inhibits for functions that could cause catastrophic events
    - Transmitter turn-on, Solar panel deployment, etc.
  - Environments for DSS are within current Avionics hardware baseline
    - Current design assumes use of staging connectors under development for LRO/LCROSS mission for use as DSS staging connectors
    - LV R&D kit will require low frequency measurements and a DTP
  - Baseline design does not include re-rad systems
    - DSS canister is not a Faraday cage and will see the same environment as the forward payload
  - SV to SV EMC compatibility is required
  - Forward SV Separation System only requires a maximum of 4 primary/4 secondary separation commands
  - Assume no stiffness, structural, separation or shock tests are required on electrical components
  - Access to aft spacecraft within canister provides hand/arm access only; no full body access is provided





•	3.1.2.1	Standard Electrical Interface Panel (SEIP)	
•	3.1.2.2	T-0 and Payload Circuit Dead Facing	
•	3.1.2.3.1	SV Ground Power Umbilical Wiring for Multiple Payloads (LC-41 Only)	
•	3.1.2.3.2	SV Ground Power Umbilical Wiring Resistance	
•	3.1.2.3.3	SV Ground Power Umbilical Wire Rating	
•	3.1.2.4.1	SV Signal Umbilical Wiring for Multiple Payloads (LC-41 Only)	
•	3.1.2.4.2	SV Signal Umbilical Wiring Resistance	
•	3.1.2.4.3	SV Signal Umbilical Wire Rating	
•	3.1.2.5.1	Atlas V System to Satellite Vehicle Commands	
•	3.1.2.5.1.2	Discrete Commands	
•	3.1.2.5.1.3	Switch Closure Functions	



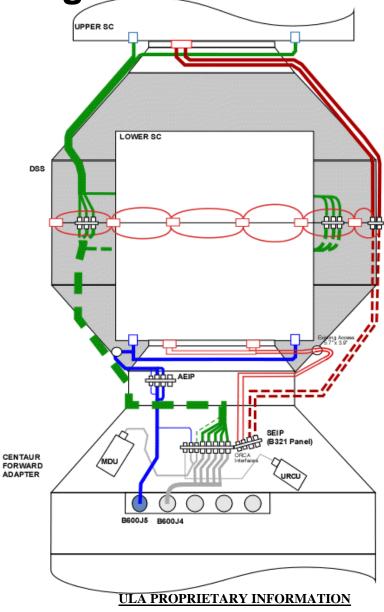


- 3.1.2.5.2.1 Separation Ordnance Power
- 3.1.2.5.2.2 Separation Ordnance Circuit
- 3.1.2.5.2.3 Electro-Explosive Device (EED) Firing Circuits
- 3.1.2.5.2.4 Separation Ordnance Firing Signals
- 3.1.2.5.2.5 Firing Signal Single Pulse Duration
- 3.1.2.5.2.6 Minimum Firing Current
- 3.1.2.5.2.7 Maximum Firing Current
- 3.1.2.5.3.2 Separation Indication
- 3.1.2.5.2.8 Firing Signal Separation Time
- 3.1.2.5.3.1 Command Monitors
- 3.1.2.5.3.2 Separation Indication
- 3.1.2.5.3.3.1 Analog Monitors
- 3.1.2.5.3.3.2 Command Verification Monitors
- 3.1.2.5.3.4 Payload Serial Data Interface



Harnessing Overview

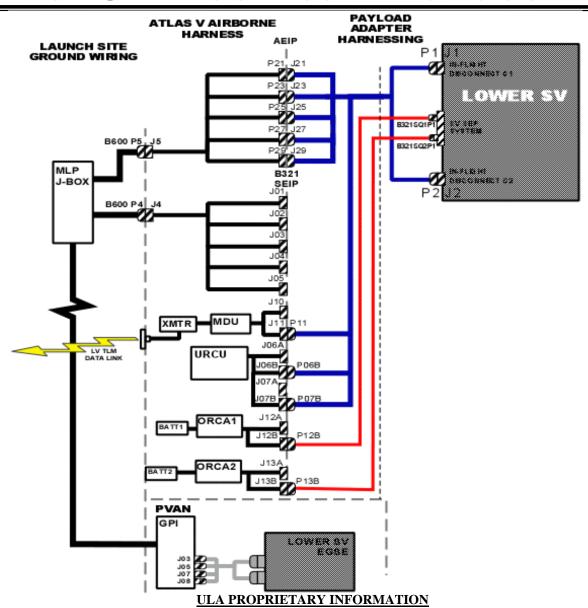






## Lower SV Electrical Interface

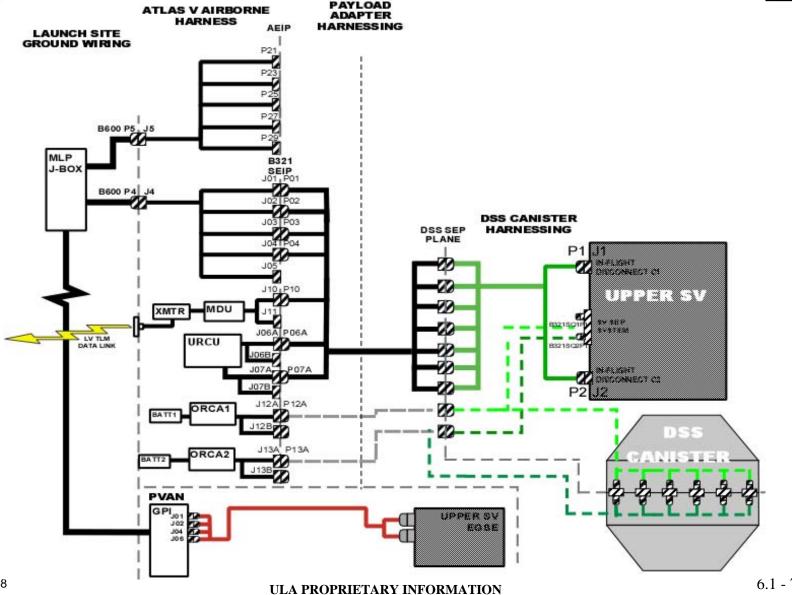






# Upper SV Electrical Interface



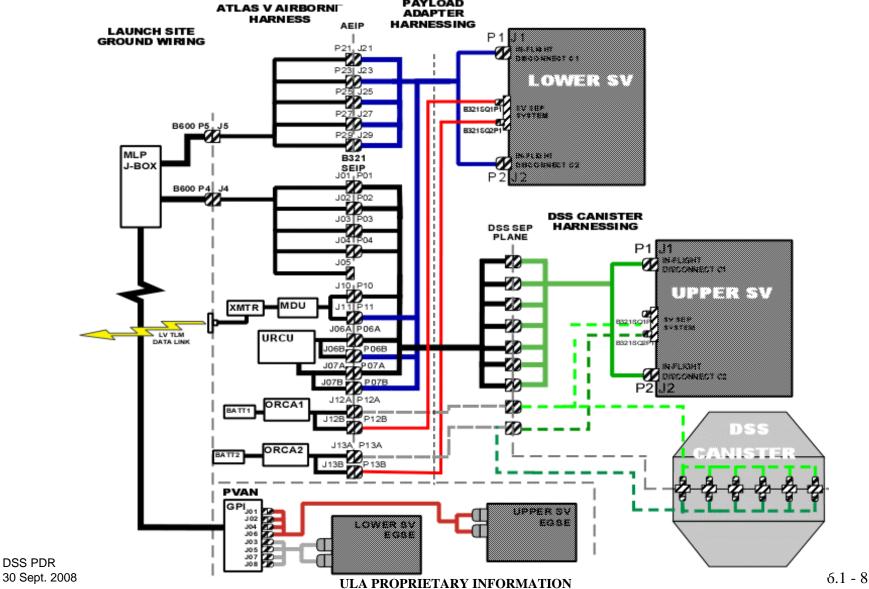




DSS PDR

# **Integrated Electrical Interface**









- Requirement
  - 3.1.2.1 Standard Electrical Interface Panel (SEIP)

The Atlas V System shall provide interface airborne electrical interconnection services, at the standard electrical interface panel, from the time of payload electrical mate to the time of umbilical separation for the umbilical capabilities and to the time of SV separation on orbit for the flight capabilities

#### Compliance

- SEIP Block change TTR-08-01217 would "reallocate" a portion of the current capability provided at the SEIP to a new interface more readily available to secondary (upper or lower SV) payload use without impact or increased risk to primary (upper or lower) SV electrical interfaces
  - Ordnance (ORCA)
    - Retain (4) primary and (4) redundant ORCA outputs at SEIP I/F
    - Move (8) primary and (8) redundant ORCA outputs to new SEIP I/F
  - Command and Control (URCU)
    - Retain (6) URCU channel 1 and (6) URCU channel 2 switch outputs at SEIP I/F (preliminary)
    - Move (2) URCU channel 1 and (2) URCU channel 2 switch outputs to new SEIP I/F (preliminary)
    - Retain discrete reference/return lines for channels 1 and 2 in the current SEIP I/F
  - Instrumentation (MDU)
    - Allocate all signals in one interface connector to an SV (J/P10)
    - All signals in other interface connector allocated to the other SV (J/P11)
    - Retain one channel of serial data in interface connector J/P10
    - Move other channel of serial data from interface connector J/P11 to a new interface connector
  - T-0 Prelaunch
    - Keep SEIP B321J/P01 thru B321J/P04 interfaces for a single SV use
    - For the other SV, use B600J05 2<sup>nd</sup> umbilical on east coast
      - » For limited T-0 functions the other SV can use SEIP B321J/P05 interface
        ULA PROPRIETARY INFORMATION

        6.1 9





#### Requirement

3.1.2.2 T-0 and Payload Circuit Dead Facing

Prior to T-0 umbilical and payload separation events, all T-0 and SV controlled payload interface circuits will be constrained to ensure that there will be no current flow greater than 10 mA direct current across the interface

#### Compliance

 The only active LV circuits during the separation events at the separation interfaces are the standard separation loop indicators

#### Verification

 Analyze the active electrical circuits across the separation planes for the Upper SC/LV separation and the Lower SC/LV separation

#### Requirement

 3.1.2.3.1 SV Ground Power Umbilical Wiring for Multiple Payloads (LC-41 Only)

the Atlas V System shall provide twenty four (24) (#12 AWG) twisted-pair wires for SV power or trickle charging functions between the SV EGSE Interface Panel in the Payload Support Room and the Umbilical Mast upper junction box which interfaces with the Launch Vehicle.

#### Compliance

- J5 second umbilical (east coast only) will provide 12 (#12 AWG) twisted-pair wires for Lower SC use
- J4 standard umbilical will provide 12 (#12 AWG) twisted-pair wires for Upper SC use

#### Verification

Inspection of Engineering





#### Requirement

3.1.2.3.2 SV Ground Power Umbilical Wiring Resistance
 The maximum round trip resistance per wire pair between the SV EGSE Interface Panel in the Payload Support Room and the SEIP shall be 1.0 ohm

#### Compliance

- Resistance, Continuity, and Polarity testing will be done at the Launch pad per ITP 9.2.19
- Lower SC interface is at the AEIP panel and can drive a slightly higher resistance requirement

#### Verification

Inspection of Engineering / Test

#### Requirement

3.1.2.3.3 SV Ground Power Umbilical Wire Rating

The maximum current through the SV ground power umbilical lines from the SV EGSE Interface Panel in the Payload Support Room to the SEIP shall be 11.0 amps per wire pair with a maximum voltage of 126 Vdc.

#### Compliance

- This is the nominal maximum loading condition that the umbilical lines can carry without damage.
- A new requirement will be levied on the SC in the event of a shorting condition at a later date

#### Verification

SV analysis / LV inspection





#### Requirement

3.1.2.4.1 SV Signal Umbilical Wiring for Multiple Payloads (LC-41 Only)

For multiple payloads, the Atlas V System shall provide one hundred twenty eight (128) shielded twisted-pair (#20 AWG) and sixteen (16) shielded twisted-triple wires (#20 AWG) for SV signal lines between the SV EGSE Interface Panel in the Payload Support Room to the Umbilical Mast upper junction box which interfaces with the Launch Vehicle.

#### Compliance

- J4 standard umbilical will provide; 60 (#20 AWG) TSP, 4 (#20 AWG) TST, 6 (#20 AWG)
   Twinax wires for Upper SC use
- J5 second umbilical will provide; 60 (#20 AWG) TSP, 4 (#20 AWG) TST, 6 (#20 AWG) Twinax wires for Upper SC use

#### Verification

Inspection of engineering

#### Requirement

3.1.2.4.2 SV Signal Umbilical Wiring Resistance

The maximum round trip resistance between the SV EGSE Interface Panel in the Payload Support Room and the SEIP shall be 5.0 ohms for each signal wire pair, or each of the signal wire pair combinations in the triplets.

#### Compliance

- Resistance, Continuity, and Polarity testing will be done at the Launch pad per ITP 9.2.19
- Lower SC interface is at the AEIP panel and can drive a slightly higher resistance requirement

#### Verification

Inspection of Engineering / Test





### Requirement

– 3.1.2.4.3 SV Signal Umbilical Wire Rating

The maximum current through the SV signal umbilical lines from the SV EGSE Interface Panel in the Payload Support Room and the SEIP shall be 3.0 amps per wire pair with a maximum voltage of 126 Vdc

### Compliance

- This is the nominal maximum loading condition that the umbilical lines can carry without damage.
- A new requirement will be levied on the SC in the event of a shorting condition at a later date

### Verification

SV analysis / LV inspection





- Requirement
  - 3.1.2.5.1 Atlas V System to Satellite Vehicle Commands

The Atlas V System shall provide eight (8) redundant pairs of SV contractor-definable control commands which can be configured as 28 volt discretes (LV power) or switch closure functions (i.e. continuity loops). The SV will provide "wrapback" capability to the SEIP telemetry connectors to verify receipt of LV generated commands.

- Compliance
  - SEIP Reallocation: each SV will get different amounts of switches depending on need
    - SV
- (6) primary switches (channel 1) preliminary
- (6) redundant switches (channel 2) preliminary
- other SV
  - (2) primary switches (channel 1) preliminary
  - (2) redundant switches (channel 2) preliminary
- 3.1.2.5.1.2 Discrete Commands can only be wired in a block of (4) redundant pairs or (8) redundant pairs
  - Voltage: "On" state +23 V DC minimum to +33 V DC maximum
  - Current: 500mA maximum per discrete
  - Pulse Width: 10 sec maximum, 20 msec minimum
- 3.1.2.5.1.3 Switch Closure Functions can only be wired in a block of (4) redundant pairs or (8) redundant pairs
  - Voltage: +22 VDC minimum to +32 VDC maximum
  - Current: 1.0 A maximum
  - Pulse Width: 10 sec maximum, 20 msec minimum
  - Leakage Current: 1 mA
- Verification
  - Inspection of engineering / Test (SIL, FASTER, Launch Site)





### Requirement

- 3.1.2.5.2.1 Separation Ordnance Power

Separation ordnance power shall be provided by the Atlas V System to the primary and redundant LV-provided DSS initiators and SV-provided initiators.

### Compliance

 Power is provided from the Primary Pyro Battery and Second Pyro Battery to fire DSS, Lower SV and Upper SV primary and redundant initiators

### Verification

Analysis / Test (Launch Site)





#### Requirement

3.1.2.5.2.2 Separation Ordnance Circuit

Each SV separation ordnance circuit (primary and redundant) shall use separate power sources and separation control circuits.

#### Compliance

- Atlas uses one primary Battery to fire (2) primary sep ordnance circuits on the Upper SV, (6) primary sep ordnance circuits on DSS and (4) primary sep ordnance circuits on the Lower SV
- Atlas uses one secondary Battery to fire (2) redundant sep ordnance circuits on the Upper SV,
   (6) redundant sep ordnance circuits on DSS and (4) redundant sep ordnance circuits on the Lower SV

#### Verification

Inspection of Engineering / Test (Launch Site)

#### Requirement

3.1.2.5.2.4 Separation Ordnance Firing Signals
 Both primary and redundant separation ordnance firing signals shall be capable of firing one (1) EED at a time (in 100 msec minimum intervals) or up to the whole group of twelve (12) at the same time.

#### Compliance

- LV will provide primary and redundant sep ordnance circuits to the forward SV for 200 msec nominal
- LV will provide primary and redundant sep ordnance circuits to the Lower SV for 200 msec nominal TBD seconds after the LV fires the (6) sep bolts on the DSS canister
- Interface compatibility between DSS sep bolts and ORCA will be accomplished prior to CDR

#### Verification

Faster Testing





### Requirement

— 3.1.2.5.2.3 Electro-Explosive Device (EED) Firing Circuits A total of twenty four (24) EED firing circuits, twelve (12) primary and twelve (12) redundant, shall be provided by the Atlas V System to the SEIP for the payload separation from its adapter (or other unique pyrotechnic requirements). EEDs used will be low voltage, 1 ampere/1 watt no-fire designs that have an internal bridge wire with a resistance of approximately 1.0 ohm.

The total allowable SV resistance for each EED circuit (i.e., from SIP through payload-adapter to payload and return to SIP including EED resistance) will be in the range of 0.9 to 2.0 ohms.

### Compliance

- SEIP Reallocation
  - LV will provide primary and redundant sep ordnance circuits to the forward SC
  - LV will provide primary and redundant sep ordnance circuits to the Lower SC
  - LV will fire (6) primary and redundant separation pyro bolts which meet this requirement (separation pyro bolts are the same as baseline 4m PLF separation bolts)
- Verification
  - Test





- Requirement
  - 3.1.2.5.2.5 Firing Signal Single Pulse Duration
     Firing signals shall be a single pulse with a duration in the range of 40 ±10 milliseconds.
- Compliance
  - The ORCA system can send a single pulse with a duration in the range of 20-200 milliseconds
- Verification
  - FASTER Testing
- Requirement
  - 3.1.2.5.2.6 Minimum Firing Current
     The firing signal current for each EED circuit shall be 5.0 amperes minimum (i.e., a total of 60 amperes minimum if firing twelve (12) at the same time).
  - 3.1.2.5.2.7 Maximum Firing Current
     The firing current shall be limited at any time to 18 amperes maximum for each EED circuit.
- Compliance
  - The ORCA system will send between 5 A and 18 A per EED even with N-1 shorted EEDs case and 0 shorted EED's case.
- Verification
  - Analysis





### Requirement

- 3.1.2.5.2.8 Firing Signal Separation Time

Primary and redundant firings shall be separated at the SV's discretion by a duration of either less than five (5) milliseconds or 80 ± 10 milliseconds of the leading edges of the firing signals as depicted in Figure 3.1.2-2. The SV will specify to the Atlas V System the desired firing sequence and firing signal separation choice. Other pulse sequences can be accommodated on a mission unique basis.

### Compliance

- ORCA switches can be individually controlled in 20 millisecond increments up to 200 milliseconds
- Verification
  - Faster Testing





- Requirement
  - 3.1.2.5.3.1 Command Monitors

The Atlas V telemetry system shall indicate the state (on/off) of each SV contractor-definable control commands.

- Compliance
  - LV can monitor each URCU switch with the MDU
  - LV can monitor each PYC relay with internal PYC circuitry
- Verification
  - Test
- Requirement
  - 3.1.2.5.3.2 Separation Indication

The Atlas V telemetry system shall be able to sense, in separate interface connectors, two (2) separation break-wires provided by the SV.

- Compliance
  - SEIP Reallocation: each SV will get different amounts of breakwire circuits depending on need
    - SV
      - (12) Command Monitors (J10)
    - other SV
      - (10) Command Monitors (J11)
  - DSS will require monitoring of up to (6) breakwires for canister separation
- Verification
  - Inspection of Engineering





- Requirement
  - 3.1.2.5.3.3.1 Analog Monitors

The Atlas V System shall provide the capability to monitor eight (8) SV analog signals for interleaving into the Atlas V System telemetry stream for transmission to the ground.

- Compliance
  - SEIP Reallocation: each SV will get (4) Analog Monitors depending on need
    - SV
      - (4) Analog Monitors (J10)
    - other SV
      - (4) Analog Monitors (J11)
- Verification
  - Inspection of Engineering
- Requirement
  - 3.1.2.5.3.3.2 Command Verification Monitors

The Atlas V System shall provide the capability to monitor sixteen command verification monitors for interleaving into the Atlas V System telemetry stream for transmission to the ground.

Each command verification monitor is capable of receiving and processing single-ended bi-level input signals .

- Compliance
  - SEIP Reallocation: each SV will get (8) Command Verification Monitors that can be used as additional breakwires if necessary
    - SV
- (8) Command Verification Monitors (J10)
- other SV
  - (8) Command Verification Monitors (J11)
- Verification
  - Inspection of Engineering





- Requirement
  - 3.1.2.5.3.4 Payload Serial Data Interface
     The Atlas V System telemetry system shall provide the capability to accept two (2) channels of serial data from the SV at the SEIP for interleaving into the Atlas V System telemetry stream for transmission to the ground.
- Compliance
  - SEIP Reallocation: each SV has the option to get (1) Serial Data channel with the option for an SV to use 2 channels of serial data if the other SV does not require any
    - SV
      - (1) Serial Data (J10)
    - other SV
      - (1) Serial Data (new connector)
- Verification
  - Inspection of Engineering / Test



# **Summary**



- Fairly mature concept exists for the Avionics design of DSS
  - All engineering still needs to be completed and released
  - Some support from other IPTs is required to complete the Avionics Design
    - Stages, Dynamics, Control Dynamics, Technical Management

### **Ready To Proceed to CDR**







### Section 6.2

### **EMI/EMC**

Greg Plamp/Bonnie Birckenstaedt



# **EMC** Requirements Not Addressed



- The following Atlas V System Specification Requirements (11000-98-022, Rev. F) will not be addressed
  - Paragraphs 3.10.7.3, 3.10.7.5, 3.10.7.7, 3.10.7.7, 3.10.7.8 and 3.10.7.9
    - Rational presented during the SRR



# Launch Vehicle Electromagnetic Compatibility (EMC)



- Paragraph 3.10.7.1
  - The Launch Vehicle shall provide for EMC with electromagnetic interference (EMI) safety margins (EMISM) of 20 dB for pyrotechnic devices and 6 dB for all other mission critical circuits.
- Design
  - All ordnance and control circuits (power and telemetry) shall be double shielded or single shielded, respectively
    - Instrumentation circuits are unshielded
  - 30 mm (1.18 inch) spacing maintained between cable categories
    - All cable categories, except for ordnance, come together at the 61 pin lift-off connector (present configuration)
      - Ordnance lines have dedicated connectors
  - Non-ordnance harnesses shall cross ordnance harnesses at perpendicular angle (90 degrees)
    - Minimize coupling to ordnance lines
- Verification
  - Ordnance Analysis (A) shall be performed against LC-41 Site RF Environment and LV Intentional RF Transmitters
- Planned Completion
  - Preliminary for PDR Worst Case Ordnance Cable runs (length)
  - Final at CDR All ordnance lines



# EED Preliminary Analysis Results



VIF/LC-41 Ordnance Evaluation:

DSS EED Circuit Analyzed	EMISM Calculated	<b>EMISM Calculated</b>
	DC no-fire (dB)	RF no-fire (dB)
Lower SV PSS	TBD	TBD
Canister Explosive Bolts	TBD	TBD
Upper SV PSS	TBD	TBD



### **Electrical Bonding and Grounding**



- Paragraph 3.10.7.2
  - Electrical bonding and grounding of Atlas V systems equipment shall meet the requirements specified in the TRD, 11000-96-006.
- Design
  - Chem-filmed or Alodine surfaces (MIL-DTL-5541) shall exist were metal to metal contact is required
    - Free of paint and primer
- Verification
  - Inspect (I) design drawings to insure that surface preparations meet the requirements to achieve electrical bonding and grounding criteria
- Planned Completion
  - -CDR



## **Electromagnetic Environment Compatibility**



- Paragraph 3.10.7.4
  - The Atlas V systems shall be designed for self compatibility, compatibility with the payload, and the overall system performance within extreme electromagnetic environments indigenous to the Launch Complex or in flight.
- Design
  - All ordnance and control circuits (power and telemetry) shall be double shielded or single shielded, respectively
    - Instrumentation circuits are unshielded
  - 30 mm (1.18 inch) spacing maintained between cable categories
    - All cable categories, except for ordnance, come together at the 61 pin lift-off connector (present configuration)
      - Ordnance lines have dedicated connectors
  - Other non-ordnance lines shall cross ordnance lines at a perpendicular angle (90 degrees)
    - Minimize coupling to the ordnance lines
- Verification
  - Ordnance EMISM Analysis (A) of the DSS (Paragraph 3.10.7.2) and Inspection (I) of harness designs (shielding and twisting)
- Planned Completion
  - Preliminary harness review for PDR complete
  - Complete harness review by CDR



### **System Radiation Limits**



- Paragraph 3.10.7.6
  - The unintentional radiated emissions shall not exceed the maximum allowable emissions defined in the Space Vehicle Interface Requirements document.
- Design
  - All Atlas V avionics have their unintentional radiated emissions measured
    - Test Method RE02, MIL-STD-461C/462
    - Measurement distance is 1.0 meter.
- Verification
  - Limit radiated emissions from DSS hardware to less than 100 V/m at top of the Centaur Forward Adapter (CFA) – 1.0 to 18.0 GHz
    - LV maintains required 6 dB EMISM
  - SV Interface Requirements (maximum DSS unintentional emissions) shall be analyzed (A) on Mission Unique (MU) basis
    - Emissions from harnesses, based on shielding and twisting design, shall be minimal
- Planned Completion
  - CDR



#### **Lightning Protection**



- Paragraph 3.10.7.10
  - The Atlas V systems shall incorporate lightning protection provisions as specified in the TRD, 11000-96-006.
- Design
  - The DSS is contained within the 4.0 meter PLF
    - No direct lightning attachment path to the DSS through the 4.0 meter PLF
      - Induced current on umbilical shields most likely current path
      - Shields referenced to LV structure at T-0 and SEIP
    - VIF/LC-41 provides lightning mitigation
      - Air Terminal and Catenary Systems
- Verification
  - Verify proper bonding paths are provided through the segments of the DSS for both satellite components
    - Minimize differential voltage levels as a result of Lightning current
- Planned Completion
  - Fab Flight/Test Article verification test
  - Drawings with electrical bonding requirements
    - Defines areas free of paint and primer need exposed chemical conversion coating (MIL-DTL-5541)



#### **Atlas V Space Vehicle Interface Requirements**



- Presently, no SVs have been defined for the DSS application
  - SVIR requirements shall be addressed during integration processes for the first flight article on a MU basis
- 3.1.2.6.1.1 Signal Reference (I)
- 3.1.2.6.1.2 Primary and Secondary Power Leads (I)
- 3.1.2.6.1.3 Chassis Ground to Current (I)
- 3.1.2.6.2.1 Umbilical Isolation (I & T)
- 3.1.2.6.2.2 Switch Closure Isolation (T)
- 3.1.2.6.3.1 Ordnance Shielding (I)
- 3.1.2.6.4.1 Atlas V System to SV Mating Surfaces (I)
- 3.1.2.6.4.2 Interface Connector Bonding (I & T)
- 3.1.2.6.4.3 Interface Connector Shield Termination Bond (I)
- 3.1.2.6.5.1 Electromagnetic Interference Safety Margin (EMISM) (A)
- 3.1.2.6.6.1 Maximum Allowable Payload Radiated E-fields (A)
- 3.1.2.6.6.2 Maximum Allowable LV Radiated E-fields (A)
- 3.1.2.6.6.3 Broadband Radiated Emissions Due to ESD (A)
- 3.1.2.6.6.4 PLF Electrostatic Discharge (A)
- 3.1.2.6.6.5 PLF Broadband E-field Limits (A)

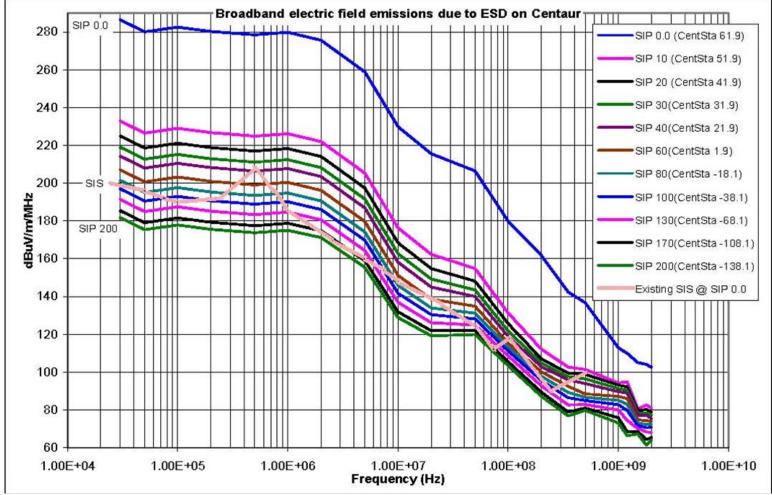
Note: (A) – Analysis, (I) – Inspection and (T) - Test



#### **Broadband Radiated Emissions Due to ESD (MU)**



 Paragraph 3.1.2.6.6.3 - The curves presented below define the latest broadband radiated emissions from an ESD event for materials on Centaur – SRI Test Results (Atlas-Avionics-2008-073)





#### Risks/Issues/Concerns



- SVs will not have a re-rad system
  - SVs must demonstrate that required inhibits on RF payloads are in place to meet EWR 127-1
  - RS-422 Telemetry, Antenna Hats, RF disconnects, etc. are alternative methods to communicate with the SVs
- No definition of the first flight article, dual SV configuration, does not allow SV RF impacts on ordnance to be evaluated
  - SV resonant cavity and direct RF environment will impact EMISM calculations 3.10.7.1
- Overall risk to violation of EMISM criteria are considered "Low"



#### Remaining Tasks



- Remaining Tasks
  - CDR
    - Finalize Ordnance EMISM evaluation for LV intentional and site RF sources (LC-41)
    - Complete harness and structural drawing inspections for requirements compliance (shielding, twisting, separation and electrical bonding)
  - ILC
    - Impact from dual SV RF operations need to be evaluated on a Mission Unique basis
      - RF resonant and direct RF environments need to be evaluated
        - » Ordnance EMISM calculation updates required (Mission Integration)
        - » LV avionics SV RF impacts need to be evaluated (Mission Integration)





#### **Ready To Proceed to CDR**







#### Section 7.0

#### **DSS Manufacturing/Producibility - Harlingen**

Ralph Luaces





- Requirements
- Assumptions
- Production Flow
- Shop floor Layout
- Production Work Instructions
- Tooling
- Shipping Containers
- Production Operations
- Schedule
- Risks
- Summary



#### Requirement(s)



- ULA Harlingen Operations Will Manufacture
  - DSS Canister (Includes 2 Canister Halves Each Similar To Generic Forward Adapter Structure)
  - DSS Canister Plug (Similar To Generic Forward Adapter's Stub Adapter)
  - C-13 Adapter
  - Lower Conical Adapter



#### **Assumptions**



- Canisters From Current Generic CFA Configuration
- Majority Of Existing Parts To Be Used
- Existing Major Tools Can Be Used
  - -Subassembly
  - -Equipment Module
  - Stub Adapter And Mate
- Transition Ring Same Size With Horizontal Flange
- Aft Ring Same Thickness And Diameter
- No Foam, Rails, Hinge Fittings, Explosive Bolt Fittings (Boattail Style), Umbilical Panel, Ground Planes, Cable Tray.
- Canisters And Plugs Primed And Painted Exterior Only.



#### **Assumptions**



- Denver Provides PSR's.
- One DSS Per Year
- Parallelism Correction From End To End Required.
- Stubs And Canister Halves Are Not Interchangeable.
- Canisters, Order Of Stack Fixed After Assembly.
- Alignment Feature In The Separation Fittings.
- Tooling Holes On Fwd And Aft Rings.
- Pre-Design Kaizen Event Scheduled For October 7-8, 2008



## **Assumptions**



- Fwd And Aft Interface Hole Patterns On C13
- Harlingen Procure And Ship Lower Conical Adapter To Site



#### **Production Flow - Canister**



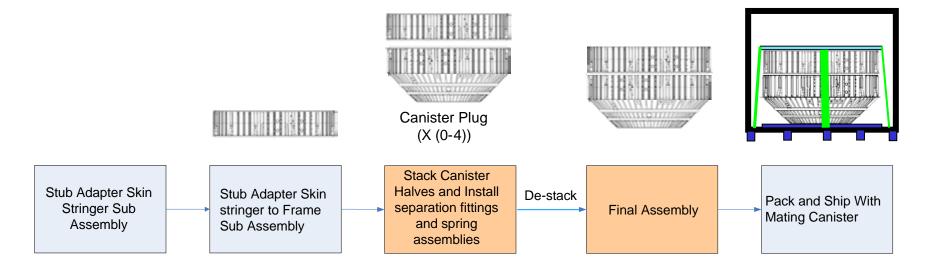
#### **Upper Canister Half Equipment Module Equipment Module** Skin Stringer frame Skin stringer Sub Sub Assembly Assembly Mate Equipment Module Sub Assembly To Stub Adapter Stack Canister Halves and Install Explosive Stub Adapter Stub Adapter Skin De-stack **Bolt Fittings and** Final Assembly Skin/stringer Stringer Sub **Separation Spring** frame sub assembly Assembly Brackets Rollover lower Lower Canister Half Canister Half **Equipment Module Equipment Module** Pack and Ship in Skin Stringer Frame Skin Stringer Sub Separate Containers Sub Assembly Assembly Mate Equipment Module Sub Assembly To Stub Adapter Orange Boxes Indicate Stub Adapter Skin Frame Sub Stringer Sub Assembly **New Processes** Assembly

DSS PDR 30 Sept. 2008



#### **Production Flow - Plug**





#### Orange Boxes Indicate New Processes



#### **Production Flow – C-13**

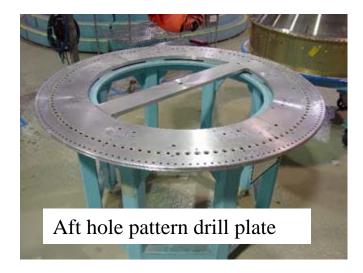


- To Be Very Similar To Current C-Adapter Processing
- C-13 Adapter Will Have Same Interface Pattern At Both Ends

#### C-13 hole pattern drill



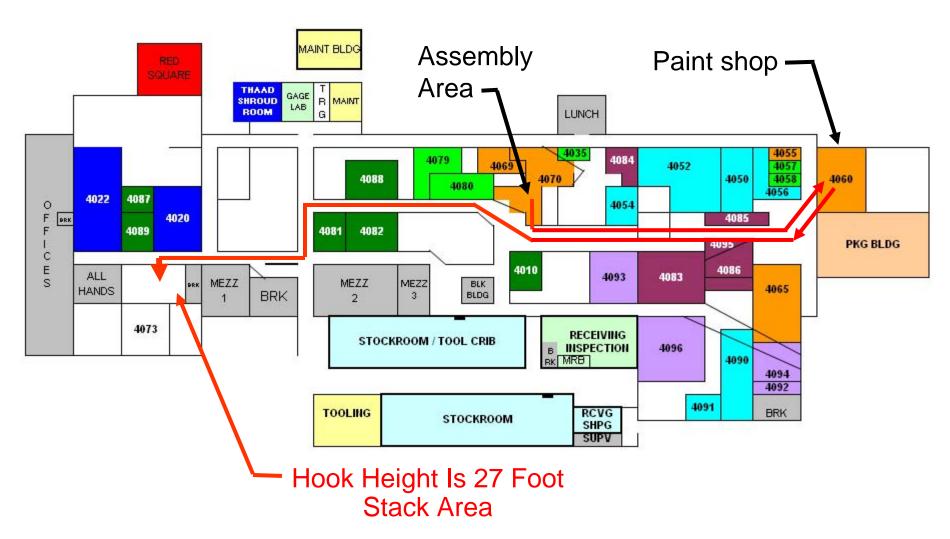






#### Shop floor Layout







## **Production Work Instructions**



- Canister Planning Will Be Similar To CFA
- Portions Of The Harness Installations Will Be Similar
- New Planning To Install The Separation Fittings And Springs.
- New Handling Procedures.
- New Planning For Stack Of Canisters

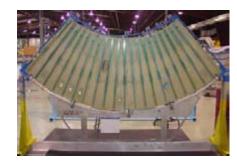


#### **Existing Tooling**





Skin stringer Assembly fixture Equip. Module



Skin stringer



Equipment Module Sub-Assembly



Skin Stringer Assembly Fixture Plug



Skin stringer



Stub Adapter Sub-Assembly and Mate



#### **New Tooling**



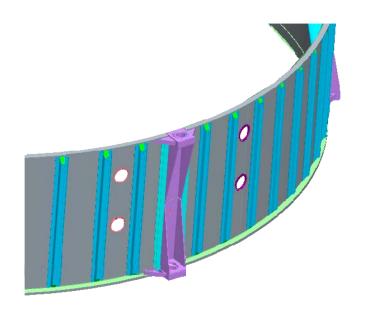
- Rollover Fixture
- Mate Tool
  - Requires Work Platforms Inside And Out
  - Lower Canister Half To Rest On Transition Ring
- Explosive Bolt Fitting Locating Tool
- Spring Separation Bracket Locating Tool
- Guide Plate Tools
- Drill Fixtures
- (2) Shipping Containers

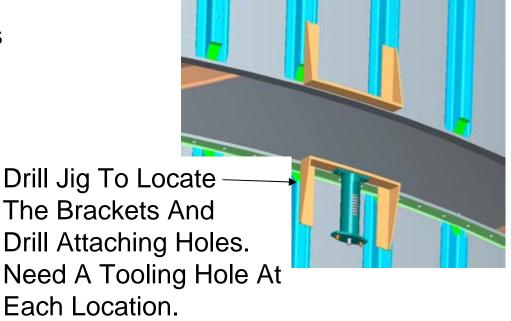


## **New Tooling**



# Drill Jig To Locate Parts And Drill Holes In Flange And Skins

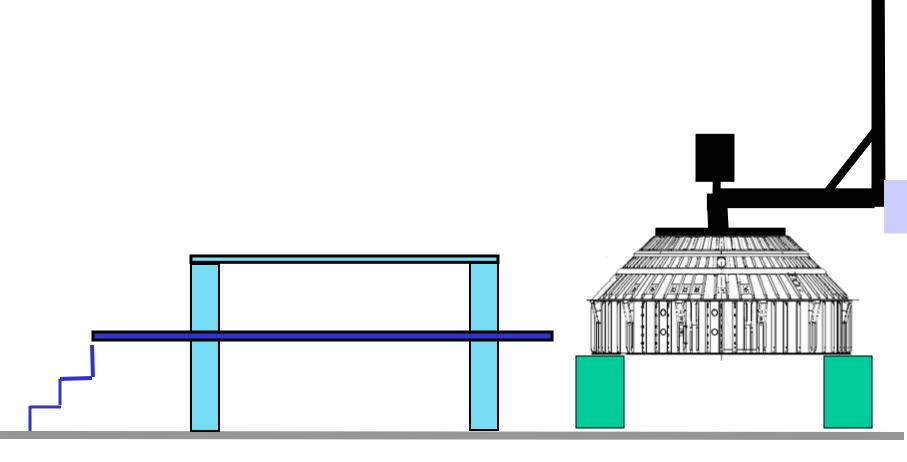




This Work Can Be Done Out Of Fixture

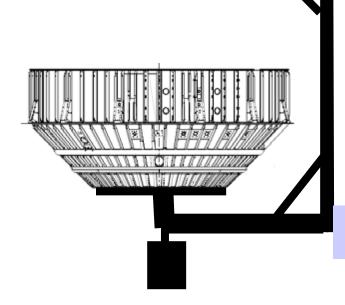


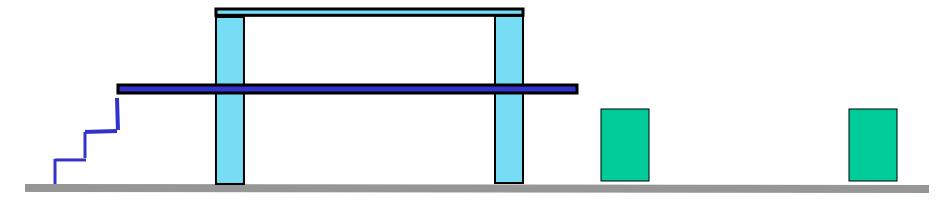






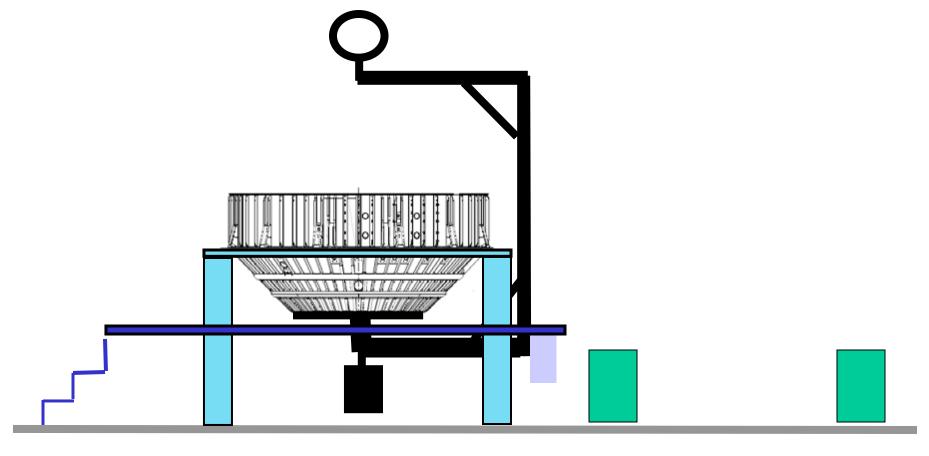








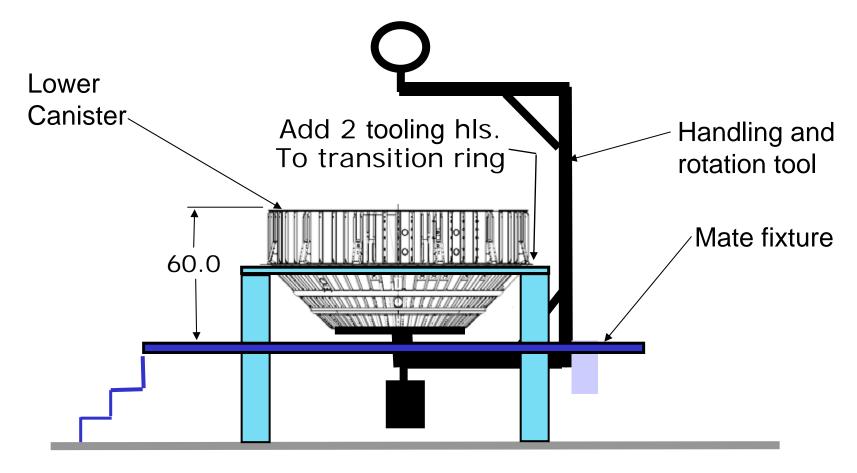




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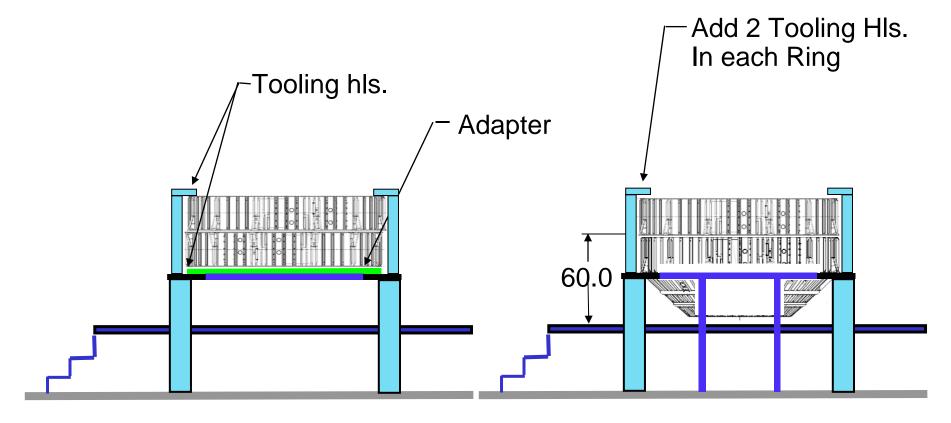




#### **Mate Stub to Stub and Canister**



•Work Platform Lifted In After Canister Half Is In Place.



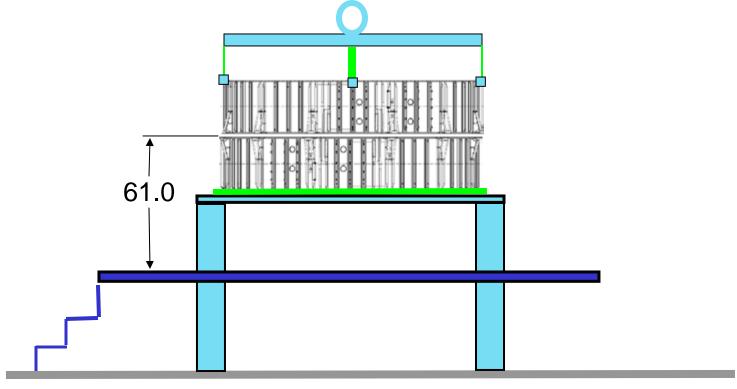


## New – lifting beam



•Lifting Beam Will Attach To The Ring (4) Places.

 Beam Will Be Used For all Moves after rotation.

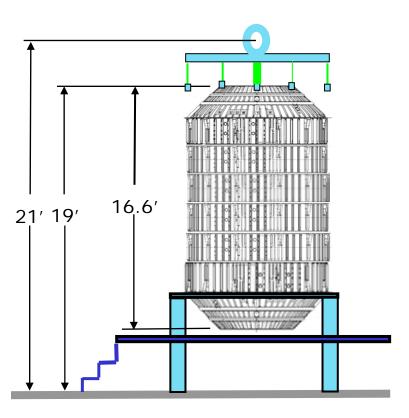


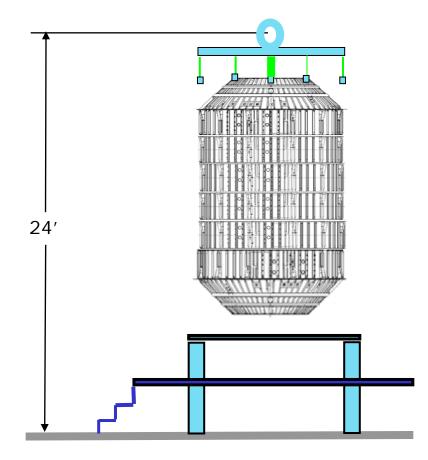


#### **Total stack height**



#### Total Hook Height Is 27 Feet





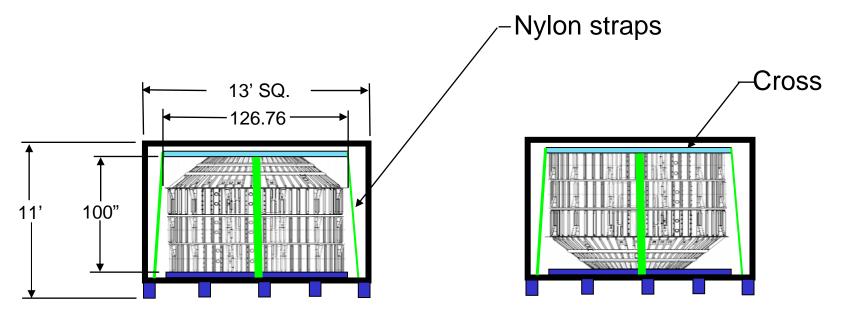
DSS PDR 30 Sept. 2008



## **Shipping Containers**



- Container Will Handle The Canister And 0 2 Plugs
- Two Containers Required.





# Production Operations

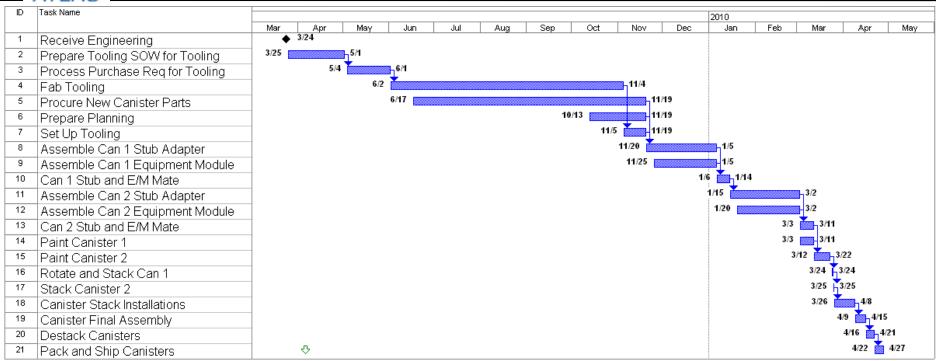


- DSS Processing Similar To CFA
- No Impact To Training
- Same Skill Set



#### **Schedule**









- Roundness Requirements
  - Risk Low
  - Add Guide Plates To Structure
- Canisters To Be Built As Matched Sets
  - Risk Low
  - If A Canister Half Is Deemed Unusable A New One Will Have To Be Built Using The Other Half
- Holding Concentricity And Flatness From Bottom To Top Of Canister
  - Risk Low
  - Resolution At PDK Event In October
- Tool Constraint- Standard Span For Complete Canister Is 80 Calendar Days Plus 33 Days Per Plug
  - Risk Low
  - Additional/Extended Shifts Or Purchase Rate Tooling



#### Summary



- Harlingen Will Assemble
  - DSS Canister and Plugs
  - C-13 Adapter
- Harlingen Will Procure And Ship Loose
  - Lower Conical Adapter
- Assumptions
  - Based On Data Available
  - Validated At The DSS PDK Event Oct. 7-8
- Production Flow
  - Similar To Existing Production
- Tooling
  - Existing Tools For Generic Build Up
  - New Tools For Stack And Processing Of Canister
- Risks
  - Controlling Overall Features On Canister
  - Canister Halves Matched Sets
  - Tool Constraint

#### **Ready To Proceed to CDR**







#### Section 8.0

#### Payload T&H MGSE

(Propulsion IPT)

**Rez Zarei** 





- Requirement(s)
- Compliance (Design Overview)
- DRD Requirement Changes/Verification Plan
- Risk
- Remaining Tasks
- Summary



### **Driving Requirements/Ground Rules/Assumptions**



- Payload T&H GSE to accommodate DSS (Encapsulate, Transport, Mate)
- 5 DSS Configurations (0-4 plugs)
- Use 4m SQ Tube Torus GSE for DSS missions in order to accommodate 4m XEPF payload fairing Configuration. Round Tube Torus can only support missions with LPF and EPF fairings
- Torus interface to Lower SV lift fitting will be at same location (height, clocking, radial distance)
- Fairing alignment operation will be performed with Flight Conic PLA (Aft portion) / C13 PLA combined assy. STV support post height will be revised to compensate for flange of Conic PLA
- Any SV access required must be provided using existing GSE work stands and diving boards.
- Single SV shock recorders and accelerometers will be used for DSS
- SV purges will be mission unique
- Transport ECS shall be same as single SV mission. The are no existing GSE to connect to lower inlet ECS during transport.
- Single SV Temp/Humidity recorder configuration will be used to support DSS during Transport and Hoist



#### **Driving Requirements/Ground Rules/Assumptions** ATLAS (Cont.)



- No Align Guide (for centering) required for lowering the fwd canister or plugs over the Lower SV when on STV. Taglines will be used (similar to lowering 5m Base Module over Centaur)
- Harlingen will deliver Canisters and Plugs in flight orientation. No existing turn over sling.
- Cape Ops will retain two to three Payload Mate Fixtures to support **DSS** mission
- Fwd SV is mated to Fwd Canister on the STV (as apposed to on the ground) otherwise a more involved sling will be required that would have to clear the SV envelope and get to lift points on the Canister). In addition, anti tipping bumpers can not be used in this case.
- Existing 55-87561-2 Access Stands will be used to install the six explosive bolts at Fwd/Aft Canister interface
- Existing PLA hoist Isolation Diaphragm will be evaluated for DSS. This diaphragm normally interfaces with the C22 PLA as apposed to C13/Aft Canister
- Airborne design will provide lift fitting attach points for hoisting the Plugs.

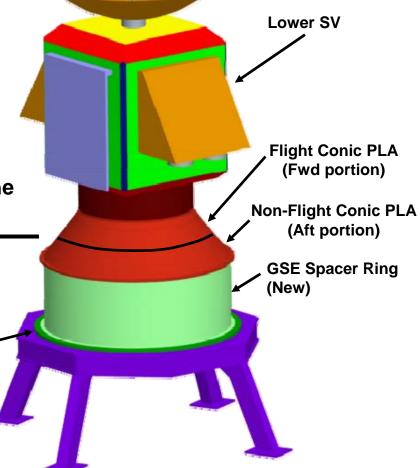


# **Install Clamp Band Sep System (Lower SV)**



- Install GSE Spacer Ring on Payload Mate Fixture (PMF) to get the Sep System to about 60-65 inch off the ground.
- Install non-flight aft portion of Conic Payload Adapter to GSE Spacer Ring
- Install flight fwd portion of Conic PLA to aft Conic PLA
  - Install non-flight bolts from underneath PMF.
- Mate SV to flight fwd Conic PLA and install the Sep System

Payload Mate Fixture (Existing)



**GSE** 

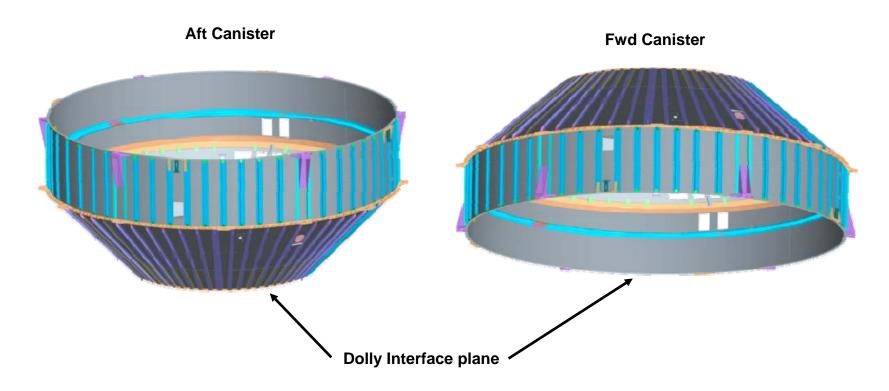
Shipping Ring (Existing)



# Canister/Plug Dollies & Container Sling (New)



- Two Dollies will be needed to transport and store Aft and Fwd Canisters and Plugs from room to room in Payload Processing Facility.
- Sling will be needed to off load Harlingen Containers from truck



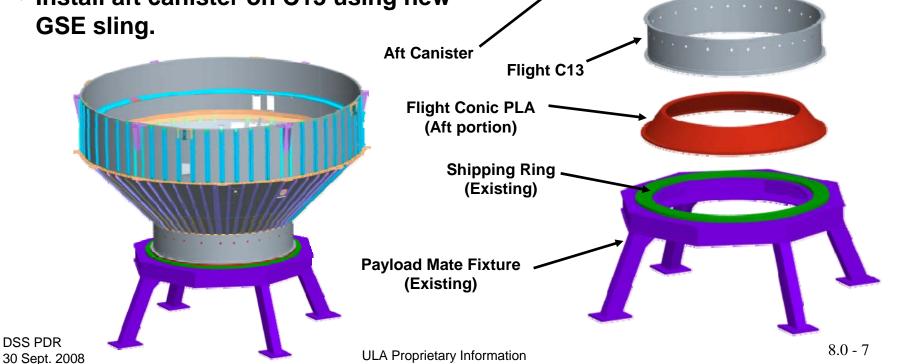


DSS PDR

### **Integrate Aft Canister and PLAs**



- Place aft flight Conic PLA on PMF
- Place C13 over aft flight Conic PLA and install both to PMF
  - Install every other bolt into aft flight **Conic PLA (threaded)**
  - Install longer bolts through every other hole attaching the assy to the PMF
- Install aft canister on C13 using new **GSE** sling.



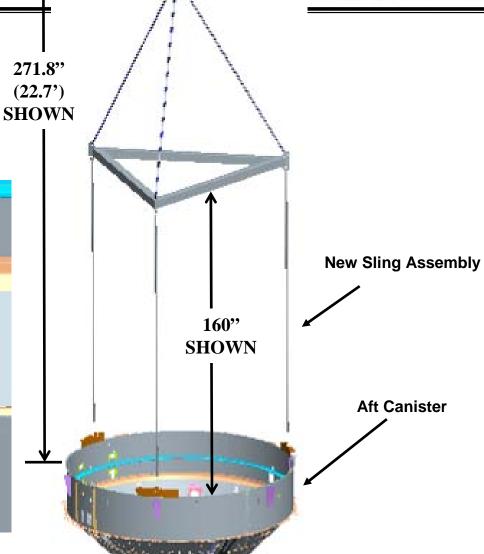


# **New Sling Assembly**



• Shorter cable length configuration shall accommodate handling of Plugs

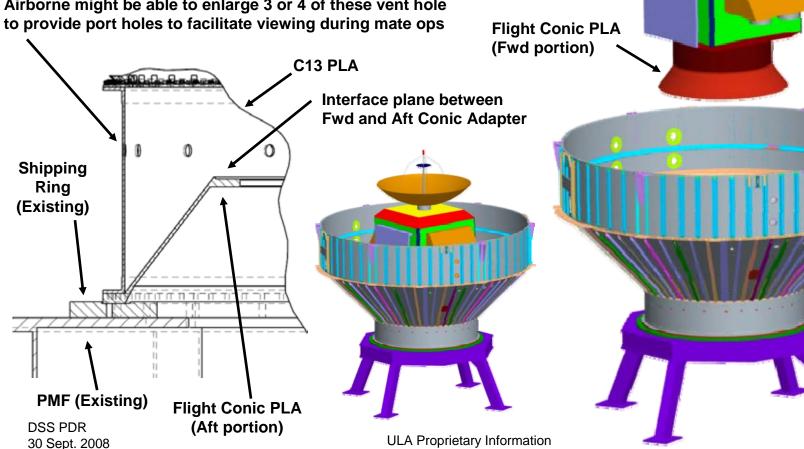
Lift Fitting interfaces with Canister Flange (3 PL)





- Install Lower Spacecraft / Fwd flight Conic PLA to the Aft flight Conic PLA.
- Install flight fasteners from below the PMF.
  - Suspended load will be addressed

Airborne might be able to enlarge 3 or 4 of these vent hole

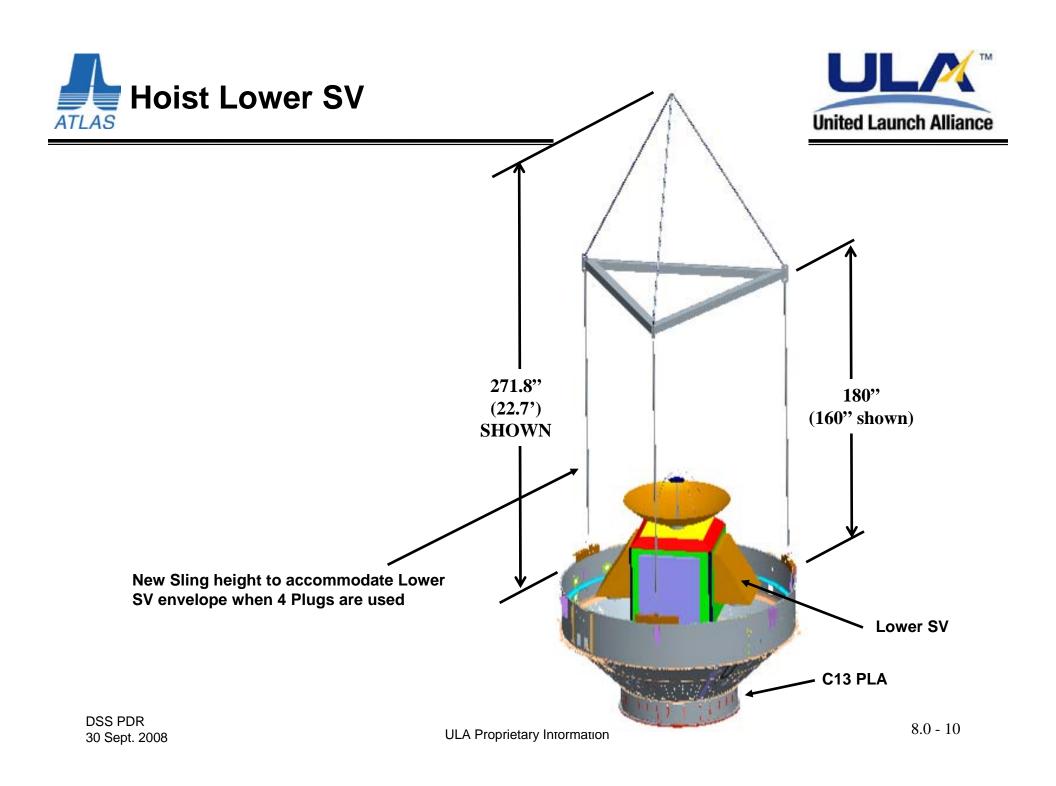


**UL/** 

**United Launch Alliance** 

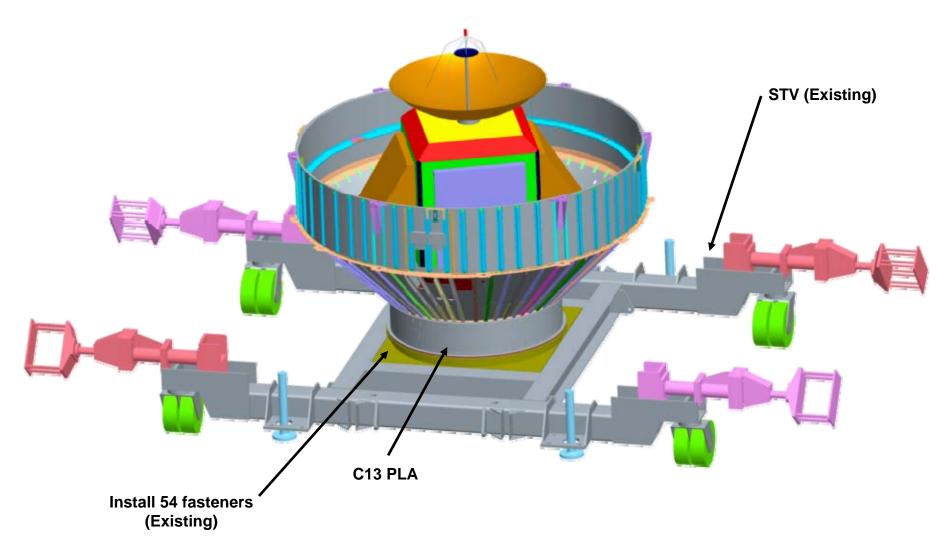
**Lower SV** 

8.0 - 9



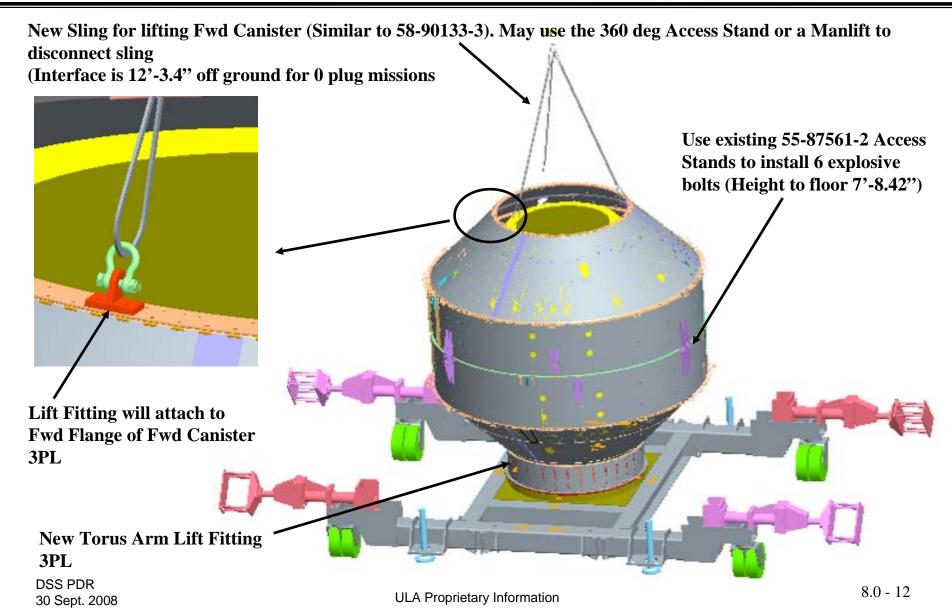








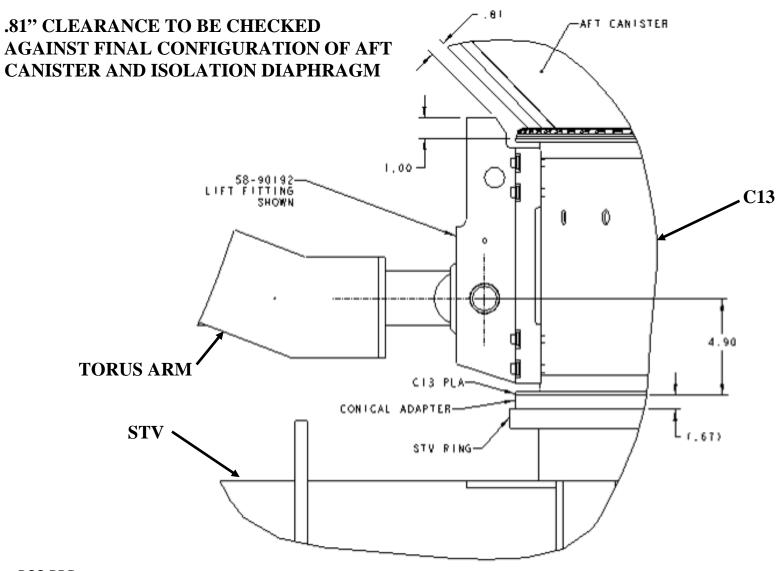






# **Install Torus Lift Fitting**





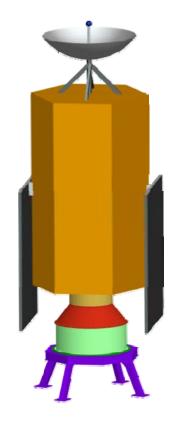


**Install Clamp Band Sep Sys (Upper SV)** 



**Upper SV** 

- Install GSE Spacer Ring on PMF
  - Spacer Ring will get the SEP Plane to 60-65 inches above floor to allow for clamp band install
- Install Upper SV flight PLA on Payload Mate Fixture
- Install Upper SV to the PLA
  - Install Upper SV separation system



GSE Spacer Ring
(New)

Shipping Ring
(Existing)

Payload Mate Fixture
(Existing)

ULA Proprietary Information

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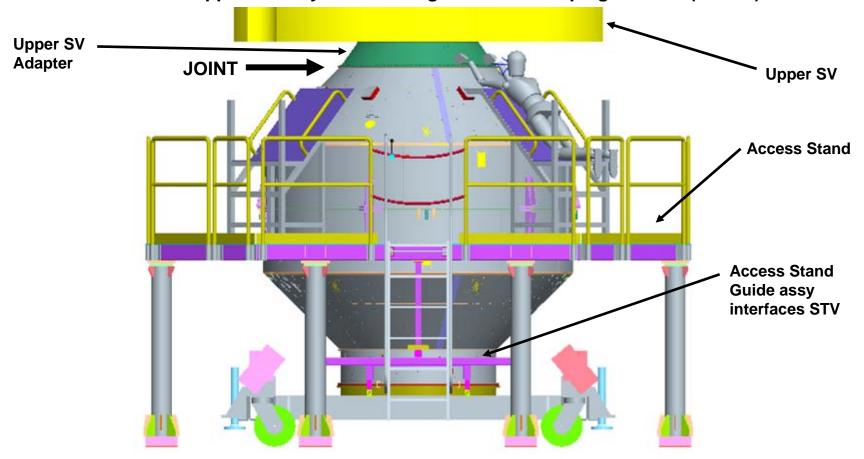
8.0 - 14

**Conic PLA** 





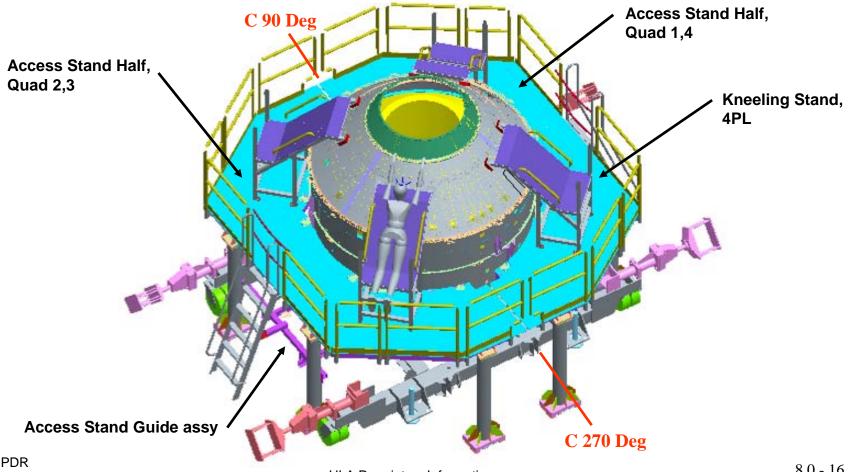
- Install Upper SV / PLA to the forward canister
  - Guide Pins (airborne) align the SV to Fwd Canister
- Assemble Access Stand (NEW) around DSS assembly prior to SV installation
- Bolted interface is approximately 12'-3.5" off ground for zero plug mission (shown)







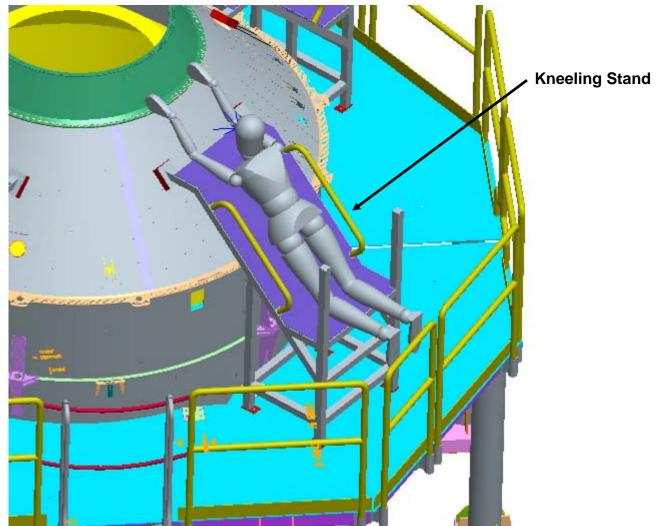
- Stand Assembly consists of two halves (similar to LRO Integration Stand).
- 2 Kneeling Stands per half will provide access for mating of Upper SV Adapter to Fwd Canister and installing 120 bolts at the interface. Kneeling Stand feet are slotted and are bolted to Stand deck. They will be in their retracted position when Stand is moved toward DSS using air bearings.







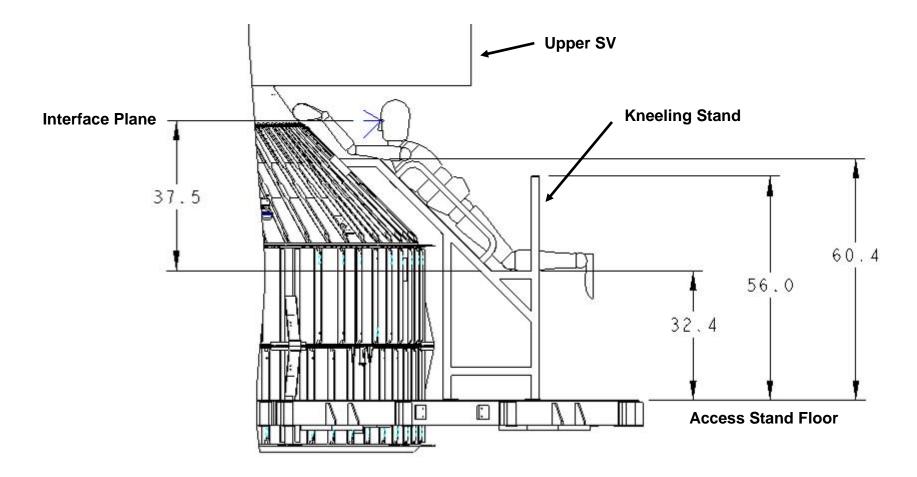
 Kneeling Stands will provide access to install 120 bolts at the Fwd Canister/PLA interface







• Kneeling Stand will be able to slide in inboard/outboard direction. It will bolted to Stand Deck prior to use.

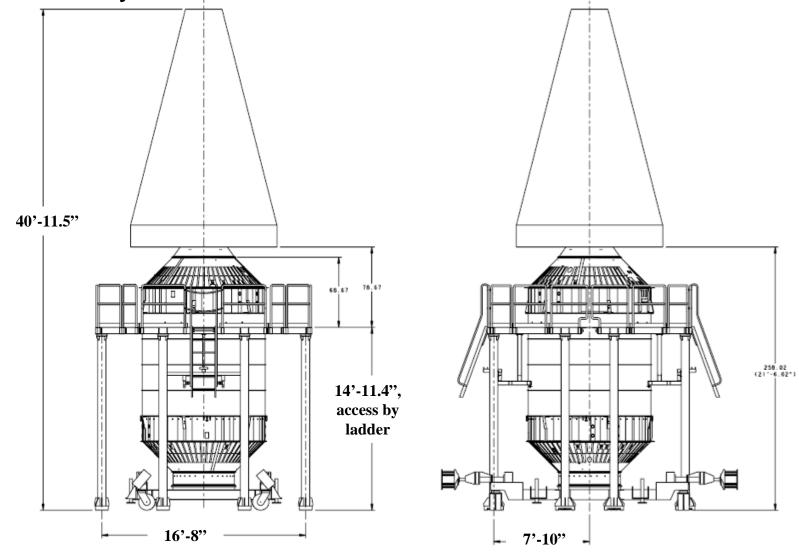




# Access Stand for a 4 Plug DSS mission



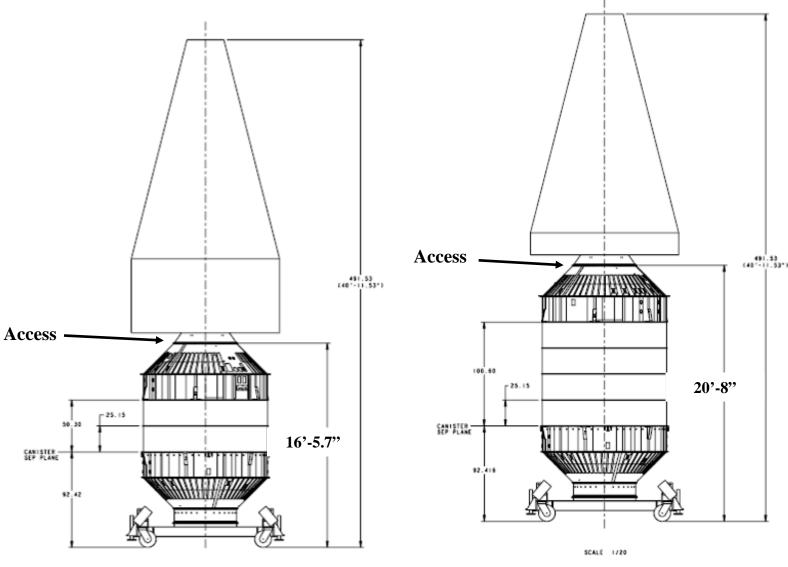
#### Stand stability and size has to be looked at





# Access height for 2 vs 4 Plugs

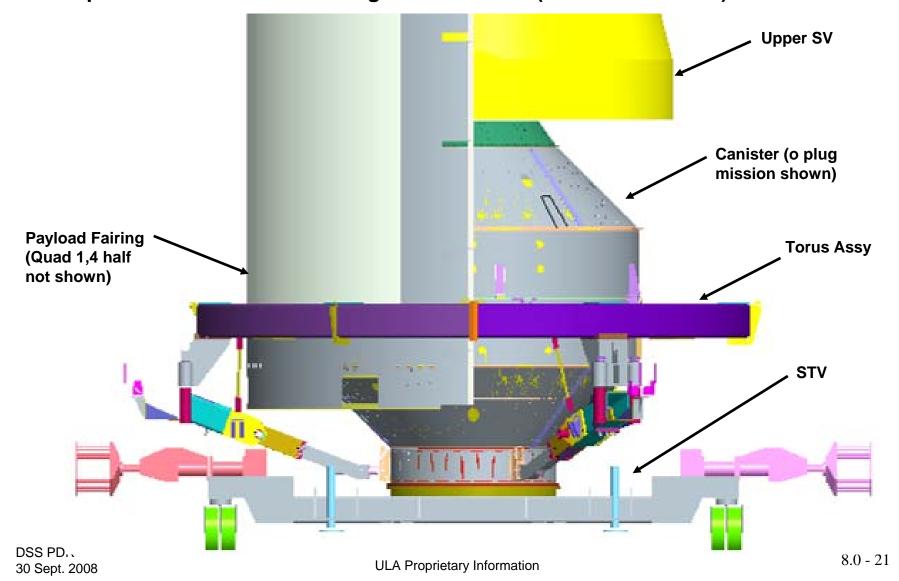








Encapsulation will be same as a generic mission (no new Hardware)







Mate at VIF will be same as a generic mission (no new Hardware) Hoist Sling not shown **Torus Ring** C13 PLA -**Boattail** 





#### Section 3.1.1 T&H Overview

- –Update the Upper Stage T&H DRD SLC-3E MGSE List of Hardware to include:
  - **➤ DSS GSE Spacer Ring**
  - **≻DSS Aft Canister Sling**
  - ➤ DSS Forward Canister Sling
  - **▶DSS Clean Room Access Stand**
- Add a new Section "3.8.25 DSS Hardware"
  - -Add a new Subsection "3.8.25.1 DSS Hardware Requirements":
    - **▶**3.8.25.1.1: "Provide a GSE Spacer Ring to allow the installation of the lower S/C separation system."
    - **▶**3.8.25.1.2: "Provide an Aft Canister Sling for hoisting the Aft DSS Canister and lower S/C."
    - **▶**3.8.25.1.3: "Provide a Forward Canister Sling for hoisting the Forward Canister."
    - **▶**3.8.25.1.4: "Provide a workstand which will allow access to attach the forward S/C to the DSS Canister, in the Payload Processing Facility."





#### Add a new Subsection "3.8.25.2 DSS Hardware Interfaces"

- **>**3.8.25.2.1: "The GSE Spacer Ring shall I/F with the Shipping Ring (existing T&H)."
- **▶**3.8.25.2.2: "The Aft Canister Sling shall I/F with the Aft Canister flange (3 places)."
- **▶**3.8.25.2.3: "The Forward Canister Sling shall I/f with the Forward Canister flange (3 places)."
- **▶**3.8.25.2.4: "The DSS Clean Room Access Stand shall provide clearance to the 4 Meter STV, the DSS Canister, and fit within the Payload Processing Facility, during operation."

### DRD Requirements Verification

-GSE hardware design/interface requirements will be verified via drawing review, analysis, and Pathfinder activity.





#### Low Risk

- All new GSE hardware will be proof load tested prior to first use however, only a Pathfinder activity can validate the GSE and the DSS payload processing flow.
- Layout to show PPF flow has not been performed. The layout is required to flush out issues or additional GSE hardware
- 4m SQ Tube Isolation Diaphragm has not been used with C13 PLA (usually interfaces with C22)
- Stand design for 3 and 4 plug missions





- Prepare layout to show PPF flow of DSS.
- Proceed with detail design of GSE required for DSS Encapsulation
  - Aft Canister and Aft Canister/Aft SV Sling Assembly
  - DSS Integration Stand Assembly (for 0 to 2 plug missions)
  - Fwd Canister Sling Assembly
  - Torus Lift Fitting
  - Storage Dollies (2) for Canisters
  - GSE Spacer Rings (2)
  - Canister Container Sling
  - Isolation Diaphragm
- Update DRD Requirements





#### DSS payload processing is feasible from GSE stand point

- Have reviewed airborne design concepts and worked with Site and airborne engineers to ensure feasibility of Encapsulation Operations
- Have modeled (in Pro E) usage of existing GSE, new GSE, and airborne hardware in payload processing to flush out all required GSE to process and encapsulate DSS
- Once both SVs are stacked on top of each other, Encapsulation of entire stack in 4m fairing, Transport to the VIF and Mate to launch vehicle is the same as single SV mission
- Have identified necessary DSS Encapsulation GSE hardware

### **Ready To Proceed to CDR**







#### Section 9.0

# **Launch Operations**

**Tony Soto** 





- Launch Operations approach to DSS and/or Atlas V System Requirement(s)
- Ground Rules for Launch Operations
- Payload Integration and sample schedule
- Summary



# Launch Operations Requirements



- Assessed impacts to Launch Operations from System Spec
- Several requirements include design, analysis, ground operations
- Focus on DSS impacts to generic processes
- DSS impacts bounded by ground rules
- Verification of DSS requirements
  - Similarity to generic payload processes
  - Mechanical Pathfinder of DSS assembly
  - Various analysis

#### Sys Spec

~ J ~ F · ·	
	Payload Encapsulation
3.1.2.6	The Ground Segment shall encapsulate the payload in the payload
	fairing.
	59617
	Approved
3.1.2.7	Encapsulated Payload Integration
	The Ground Segment shall mate the encapsulated payload with the
	integrated launch vehicle.
	11
	Approved



# Launch Operations Requirements



- Assessed impacts throughout integration process
- Look beyond the DSS hardware design to logistics, process facility, etc.

#### PAYLOAD ENCAPSULATION



**ENCAPSULATED PAYLOAD INTEGRATION TO LV** 

DSS INTEGRATION

PLA MATE X2

PAYLOAD STAND ALONE OPS SUPPORT

PAYLOAD PROCESSING ACCOMODATIONS

**DSS ELEMENT PROCESSING** 

**ENVIRONMENTS** 

SC COMMUNICATIONS (PVAN)

PLF, DSS MECHANICAL OPS / CLOSEOUTS

PAYLOAD CONTINGENCY ACCESS

**ELECTRICAL INTERFACES** 

LV ACCESS TO PSS



#### **Launch Operations Scope**



- Consider any operation / interface where DSS causes divergence from generic operations
  - Payload Operations (including related GSE) impacts at Astrotech
    - lower SC PLA mate
    - Preparation and encapsulation of SC in DSS hardware
    - Integration of upper SC with DSS
    - New interface for tension measurement at time of PLA mate and tension verification after SC mate to LV
  - Launch Ops Mechanical systems
    - Receipt and handling of DSS elements within process facility (new stands, slings, DSS dollies
    - VIF access (no new installations or VIF changes per ground rules)
    - PLF to DSS ECS duct installed in VIF
  - Airborne / Ground Electrical Umbilical instrumentation and separation cables
    - Test and installation of additional MPK harness for lower SC
    - Test and installation of additional MPK harness extensions for upper SC (extension cables)
    - PSS instrumentation cables extended for upper payload
    - No impacts to PVAN or Comm. Systems per ground rules



# PLF Encapsulation / Transport / Hoist / Mate to LV



- All encapsulation, transport and hoist operations are generic
  - Mate to CFA includes additional fasteners which are accounted for
  - Mate of PLF to Boat Tail is generic
- Installation of Lower ECS (LECS) is accounted for
- Instrument and ordnance cables to Payload Separation Systems (PSS)
   modified to eliminate need for PSS access per ground rules
- PLF Mechanical closeouts are generic
- Contingency SC access per ground rules





#### Structures

- Atlas V 4xx with XEPF (Assumes worst case, drives GSE, Payload Facility, VIF configuration)
- ULA to provide adapters and sep systems for both SC
  - Assume a qualified payload adapter and sep system (per AMPG) in both locations
  - PSS cable extension needed during PLA mate to eliminate need for access to PSS in VIF for tension measurement, read tension at CEM for both SC
- Assume 0 to 4 additional plugs in DSS
  - Launch ops receives DSS in two (upper / lower) segments, regardless of number of plugs
  - Plugs part of upper DSS to facilitate lower SC mate to lower DSS
  - Largest DSS configuration will require Cape to assemble upper canister
  - Have coordinated delivery logistics, Cape labor to assemble largest upper canister configuration will be accounted for





- Structures (cont.)
  - No access to either SC following encapsulation provided for nominal LV or SC operations
  - Contingency access to both SC for PLCP only via arm size openings to each SC regardless of propulsion configuration
    - Openings in lower DSS accessible via boat tail doors or standard PLF door
    - One or two standard doors in PLF
    - No VIF modifications or new GSE (all access using existing VIF levels with access stands / diving boards)
    - Risk in case of bi-prop SC due to separation of commodity valves on SC structure
  - No access provided to measure or tension PSS after encapsulation / in VIF
    - ITP requirement to measure tension 24 hours after sc mate. Mitigation is to configure to measure tension at the CEM or use ADMS only after encapsulation.
    - This is program risk judgment based on SC de-stack to tension PSS at ASO, Mitigation is reliable process for tension with predictable tension decay
    - Remove PSS safety device. Mitigation would be to delete the safety device from both separation systems
  - Access for PLCP, PSS tensioning, tension measurement, SC misc. ops may be significant cost driver





- Structures (cont.)
  - An ECS (LECS from MLP) will interface with a diffuser on the DSS to provide air to the lower SC. Any additional ducting is considered mission unique and is not included.
    - No internal ducting to assemble within the DSS
    - No transportation configuration identified for lower SC ECS
    - Any ducting from PLF interior to DSS to be assembled after SC mate to LV





- Pathfinder used to verify DSS assembly plan
- Pathfinder definition
  - Assume SC and DSS mate operations will be conducted with representative GSE providing proper H/W elevations
  - Pathfinder conducted at ASO for purposes of estimate, no technical constraint to change in location (No on-pad / VIF operations required)
  - All flight hardware and GSE delivered to ASO SPF
  - Pathfinder ~4 days in ASO SPF
  - Start ~ L-5 months
  - No SC or mass simulators
  - Mechanical assembly and cable routing verification
  - No electrical tests
- No PVAN implications relative to power, openings or work space
  - Previous Atlas V missions have demonstrated that Number and size of SC is not an indication of PVAN utilization levels
  - Present PVAN area, EGSE power and communications interfaces will be provided to prospective customers



## **Groundrules & Assumptions**



- Astrotech (payload process facility) impacts
  - Distribute existing communications capabilities between SC operating in different cells / control rooms
  - Independent SC campaigns to point of PLA mate for both SC
  - SC PLA mates and encapsulation in SPF / Building 9 Encapsulation bay
  - ULA not responsible for transport of SC between buildings at ASO
  - No extraordinary safety or security impacts
  - Assume use of existing comm. capability from PVAN to ASO
  - Class 100K etc. standard Atlas contamination standards



## Atlas V Processing in SPF, Bldg. 9



- 1. Process DSS and PLF in Encapsulation Bay
- 2. Store in CSA
- 3. Begin Integrated Ops with Lower SC in East Bay
- Integrate upper SC to DSS in Encapsulation bay or west bay
- 5. Encapsulate in Encapsulation bay

- Considered various operations concepts through Astrotech
- Identified GSE for movement / storage of DSS Canister
- Have considered various SC process locations in ASO B2 or B9, all concepts integrate SC to DSS / PLF in B9

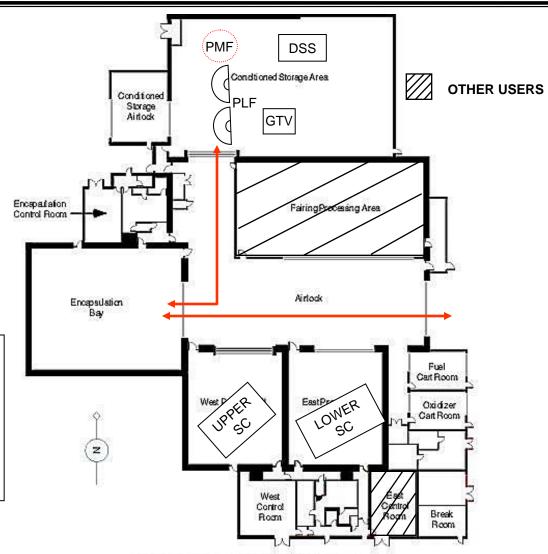
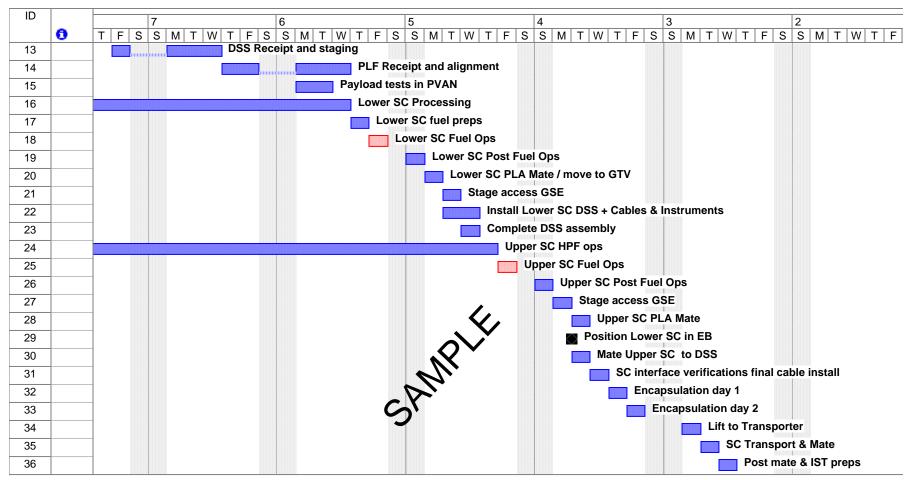


Figure 13.1-1 Building 9-Layout



## **Atlas V Sample Schedule**







#### **Launch Ops DSS Summary**



- Have identified DSS operations impacts
- Impacts are constrained by ground rules
- Some ground rules may be challenging for SC / Atlas
  - Fill drain valve configuration
  - Access limitations
  - Communications limitations
- Have reviewed Ops Concept and commented to GSE, Hazards, changes in process
- Accounted for use of 0 to 4 plugs in DSS
- Produce detailed operations plan / schedule
- Review of flight hardware, GSE, and changes to ops concepts low risk

## **Ready To Proceed to CDR**







### Section 10.0

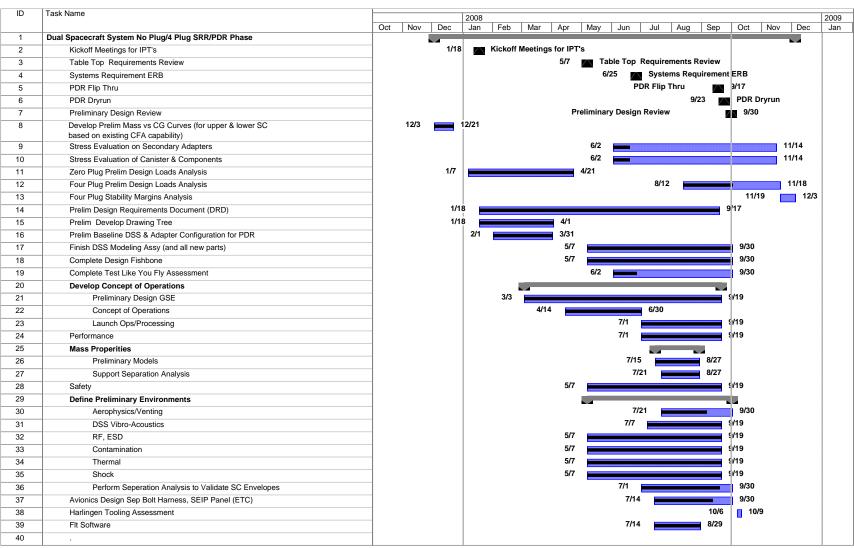
**Schedule** 

Janie Perier



#### **Dual Spacecraft System Zero Plug-4 Plug SRR/PDR Phase**

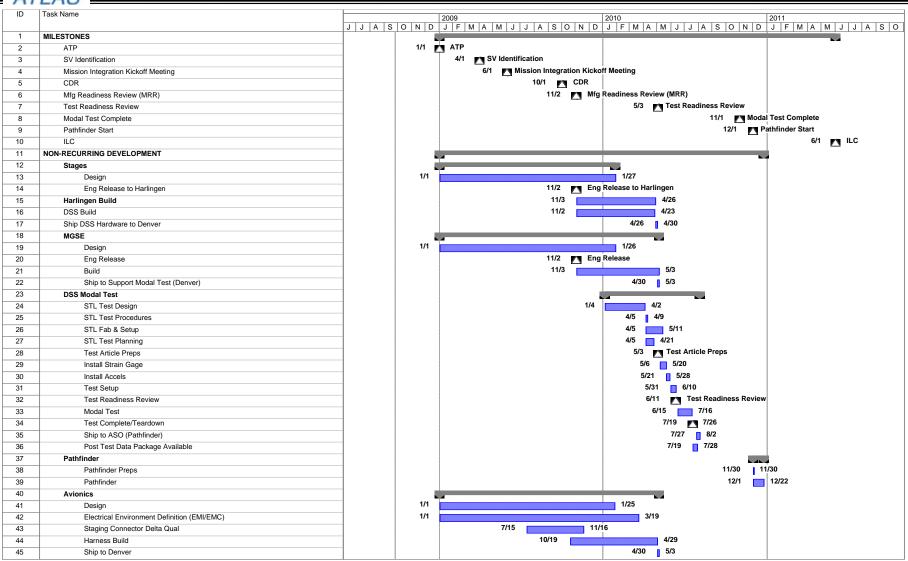






#### **Dual Spacecraft System Zero Plug-4 Plug Full Development**

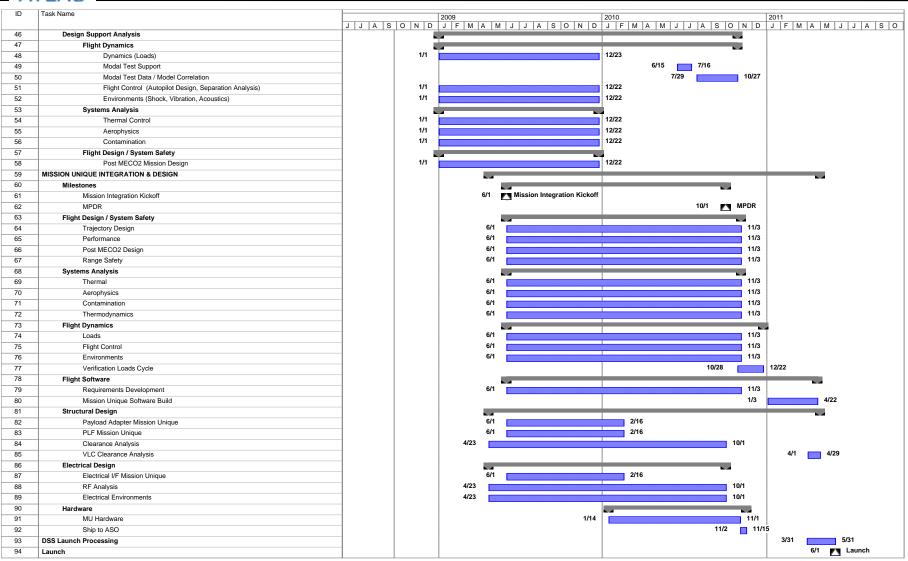






#### **Dual Spacecraft System Zero Plug-4 Plug Full Development**









Full development schedule assumes 30 month integration

## **Ready To Proceed to CDR**







# Preliminary Design Review ERB 08-1364 Dual Spacecraft System

11.0 Remaining Tasks to CDR & ILC

**Sept 30, 2008** 



## DSS Remaining Tasks



- Complete Kaizan with Harlingen (Oct 7-8, 2008)
- Closeout ERB for IRAD (Dec 2008)
- Complete Design to CDR (Sept 2009)
  - ECS Ducts
  - Sep Bolt Fittings
  - Lower Conical Adapter
  - Springs Attachment
  - Canister Halves Attachments/Interfaces
  - Opening Covers
- Avionics design analysis, release drawings
- GSE hardware design & build
- Analysis Tasks (Preliminary results by Dec 2008)
  - CLA for 4-Plug Configuration
  - CLA Results used in Control Dynamics Analysis
  - CLA Results used in Stress Analysis
- Additional Analyses:
  - Thermal, Aerophysics, Contamination, ESD, Safety
- Compatibility Analysis
- Reliability Analysis
- Testing Plan TLYF Sep Bolt Fitting, ECS, Others
- Complete component testing, if required
- Fishbone Dispositions
- Kaizan Event on Assembly/Cape Operations
- Access Study
- Update Specification Documents
- Build Protoflight DSS
- Modal Testing
- Pathfinder







#### 12.0 Action Item Review

Hank Juister



# **Action Item Submittal**



- Before submitting an Action Item (AI), please try to resolve the issue/concern with the presenter before writing an AI.
- If not resolved, then submit an AI for review/disposition



## **Action Item Review**



- Review all Action Items received at this DSS PDR
- Ensure Als have Category 1 or 2, and due dates
  - Category 1
    - Issue identified must be resolved (or information requested must be provided) in order to satisfactorily complete PDR.
    - Requires formal response/closure, including, where appropriate, an agreed to closure plan before PDR is considered closed.
  - Category 2
    - Issue identified, or information requested, does not directly impact PDR, however should be addressed by the program.
    - Requires resolution, but does not necessarily require resolution for the PDR to be considered closed.







# Preliminary Design Review ERB 08-1364 Dual Spacecraft System

13.0 Summary/Wrap-up

Cathy Andrulis Sept 30, 2008



## **DSS Summary/Wrap-up**



- The Preliminary Design for the Dual Spacecraft System is complete.
  - This work has been completed during part of 2007 and the first 3 quarters of 2008.
- The team is ready and committed to continue with the design, analysis, and development of the DSS.
- Subject to funding continuation, a CDR is scheduled for Sept 2009 leading toward an Initial Launch Capability in May 2011.





- PDR Exit Criteria/Checklist (extracted from Command Media)
- Exit Criteria/Checklist
  - –Preliminary design is complete and predicted to meet all requirements?
    - >Yes shown in sections 2.0 through 10.0
  - –Program risk and opportunity management is acceptable?
    - >Yes shown in sections 4.0 through 9.0
  - -System is reliable and safe for use?
    - >Yes shown in sections 3.0, 4.0 and 5.9
  - –Test and manufacturing planning underway?
    - >Yes shown in sections 3.0, 4.0 and 7.0
  - -PDR complete?
    - >Yes all entry accomplishments are demonstrated.
  - –Authorization to proceed is granted?
    - >Yes?

## **Ready To Proceed to CDR**